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An Economic Impact Study of Particulate Emission Standards for Combustion of Low Carbon Wastes (R77-5)

Marder and Associates, Springfield, IL

Prepared for

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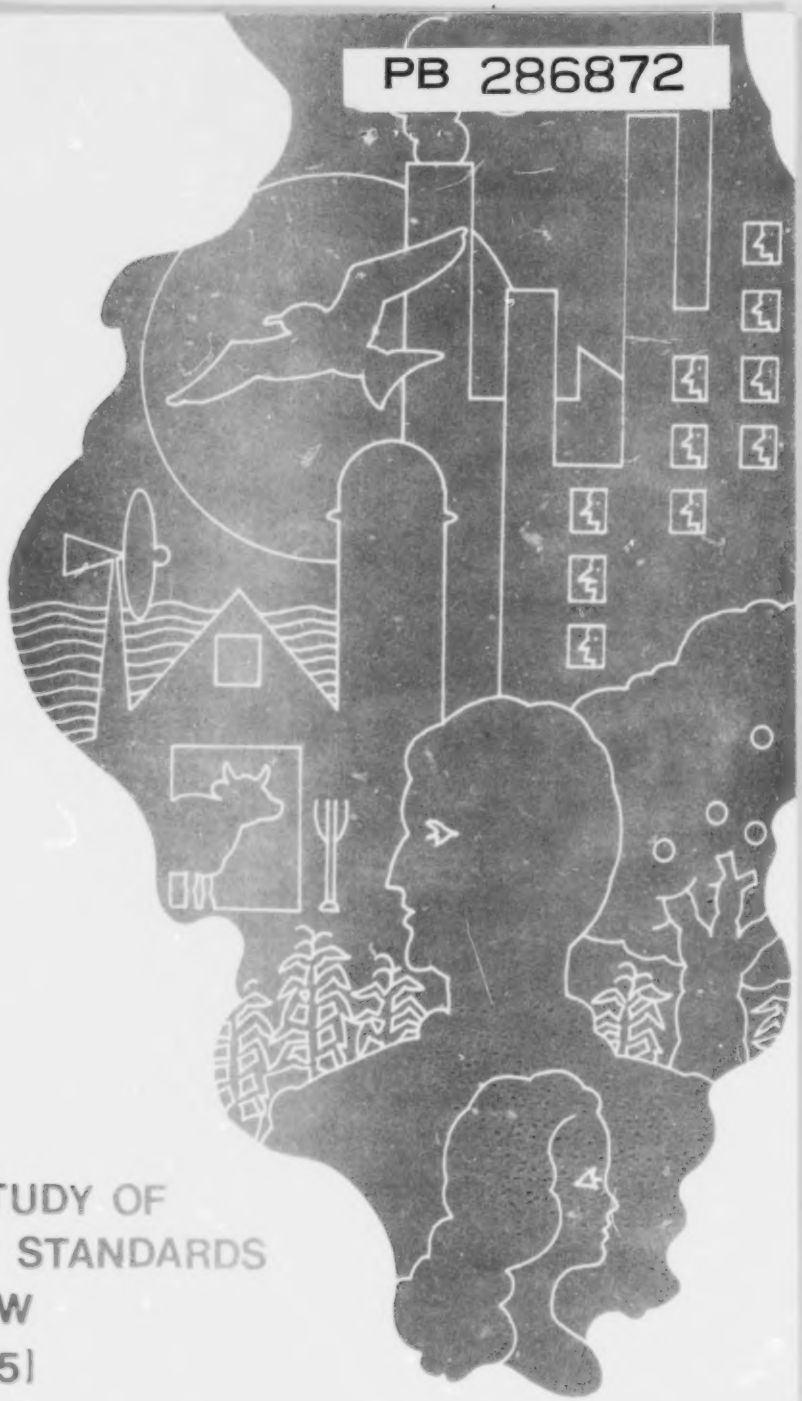

AN ECONOMIC IMPACT STUDY OF PARTICULATE EMISSION STANDARDS FOR COMBUSTION OF LOW CARBON WASTES [R77-5]

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This report analyzes the cost and benefits of the proposed regulation R77-5. (Appendix B details the existing and proposed regulations.) Adoption of the proposal would allow Addressograph-Multigraph to operate their incinerator as is, so long as certain criteria are met. The proposed regulation is also so narrow as to almost certainly limit its applicability to the Addressograph-Multigraph incinerator.

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AN ECONOMIC IMPACT STUDY OF PARTICULATE EMISSION STANDARDS FOR COMBUSTION OF LOW CARBON WASTES, R77-5

by

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This report has been reviewed by the Institute for Environmental Quality and approved for publication. With the exception of the Opinion of the Institute's Economic Technical Advisory Committee, views expressed are those of the contractor and do not necessarily reflect the position of the IIEQ.

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Opinion of the Economic Technical Advisory Committee of the Illinois Institute for Environmental Quality

The Economic Technical Advisory Committee has reviewed the economic impact study, IIEQ Document No. 78/06, entitled Economic Impact of a Proposed Particulate Emission Standard for the Combustion of Low Carbon Waste (R77-5). The Committee finds the report to be generally responsive to the requirements of Section 6 of the Environmental Protection Act and recommends that it be forwarded to the Pollution Control Board so that public economic impact hearings may be held in connection with proposed regulation R77-5, LOW CARBON WASTE, which seeks to amend Rule 203 of Chapter 2, Air Pollution Regulations.

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Special thanks are offered to Mr. Berkley Moore of the Illinois Environmental Protection Agency and Mr. Michael Friedman of the Illinois Institute for Environmental Quality.

Executive Summary

Addressograph-Multigraph Corporation owns and operates a facility for the production of reproduction print paper for use in the engineering industry. One of the operations undertaken at this facility is the incineration of liquid waste products. A problem arises in that the wastes which are incinerated have a very low carbon content. As virtually all incinerator regulations (including Rule 203[e] which is the subject of this report) rely on a carbon dioxide (CO_2) correction factor, the gas stream emitted from the Addressograph-Multigraph incinerator can not presently comply with the existing regulations.

The CO_2 correction factor is designed to prevent incinerators from circumventing the intent of emission standards by utilizing excess air. In general, incinerator regulations are written on a grains per standard cubic foot basis. This facilitates analysis, since determining the weight of particulates in a known volume of exhaust gas is a fairly simple and straightforward procedure. If a "standard" refuse is incinerated using the required amount of air to support incineration, and if the carbon content of the waste is known, then a mathematical computation of the amount of CO_2 in the exhaust air can be made. This calculation derives from the chemical reaction of oxygen and carbon to form CO_2:

$$C + O_2 \xrightarrow[\Delta]{} CO_2$$

Experience has demonstrated that under "normal" (ie. 50% excess air) conditions, the waste stream would contain about 12% carbon dioxide.

If everything else remained constant, and the operator of the incinerator doubled the amount of air used in the incinerator, the resulting exhaust gas would contain about one-half the particulates (by weight) per cubic foot than it would have, had the air inflow not been increased. However, the amount of carbon dioxide in the exhaust gas would also decline by some fifty percent. Without a common basis of comparison, a simple increase in combustion air could be used to reduce the measured emissions and thus circumvent the intent of the regulation. To avoid this, the "12% CO_2 factor is utilized. By use of this factor, a gas stream found to contain 0.05 grains per cubic foot and 6% CO_2 is assumed to have utilized additional air. The volume of air actually measured is then "corrected" to 12% by dividing by two. The amount of particulate in the "corrected volume" of gas is now 0.1 gr/SFC.

The above procedure presupposes a carbon content in the material incinerated which would yield 12% CO_2 in the exhaust gas. If, however, the carbon content of the waste yields only 6% CO_2, then the entire procedure goes awry. An analysis of the exhaust gas would appear to indicate that excess air was utilized to combust the material when, in fact, such was

not the case.

In Addressograph-Multigraph's situation, the carbon dioxide in the exhaust gas is 0.0146%, and a correction to 12% carbon dioxide indicates enormous quantities of particulates emitted on a corrected basis. For a sample showing 0.1 gr/SCF, the "corrected" emissions of Addressograph-Multigraph are 74.25 gr/SCF. If everything were held constant and the carbon content of the waste were somehow increased to 12%, the "corrected" emissions would still be 0.1 gr/SCF. It is this mathematical inconsistency that prompts the proposed regulatory change.

Simply put, Addressograph-Multigraph contends that the incinerator in question meets the intent but not the letter of the law. The company has therefore sought relief from the Illinois Pollution Control Board.

This report analyzes the costs and benefits of the proposed regulation, R77-5. (Appendix B details the existing and proposed regulations.) Adoption of the proposal would allow Addressograph-Multigraph to operate their incinerator as is, so long as certain criteria are met. The proposed regulation is also so narrow as to almost certainly limit its applicability to the Addressograph-Multigraph incinerator.

Should the Board reject the proposed regulation, Addressograph-Multigraph could comply with the existing regulation by one of three methods:

- Retrofit tail-end cleanup on the

existing incinerator;

- Utilize a totally new technology to meet applicable standards;
- Cease operations of the plant.

Capital and annual costs are calculated for all viable options. Alternatives investigated but abandoned as implausible are discussed briefly.

Retrofit can be carried out by the use of a baghouse, an electrostatic precipitator, or a Venturi scrubber. In each case the particulate removal efficiency is at the very high end of the equipment's capability. Costs associated with these options appear in Table E.1. Costs displayed include capital costs; incremental annual costs (which include the annual operating, maintenance, and capital recovery charges); and total annual costs, which include annual costs plus the costs of continued operation of the incinerator.

Two types of alternate technologies have been examined: reverse osmosis and contract disposal. Although problems have characterized the former technique, its use with similar wastes prompted its inclusion herein. Contract disposal would basically replace current incineration. Its cost depends upon the price per gallon encountered by Addressograph-Multigraph. Because this rate is uncertain, a high and low estimate are determined. Table E.1 summarizes these projected costs.

TABLE E.1

Costs of Particulate Removal Options

	Initial Capital $	Incremental Annual Costs $	Total Annual Costs $
Incineration	60,000	109,200	109,200
Baghouse[1]	46,703	14,419	123,619
Venturi Scrubber[1]	82,772	30,172(23,072)*	139,372(132,272)*
Electrostatic Precipitator[1]	91,577	17,960	127,160
Reverse Osmosis[2]	90,000	23,760	33,360
Contract Disposal[2] (High)	- 0 -	137,280	146,880
Contract Disposal[2] (Low)	- 0 -	72,800	84,200

[1] These three options can only be run in conjunction with the incinerator. Therefore, the last column (Total Annual Costs) includes the cost of operating the incinerator ($109,200) and the cost of running the retrofit option.

[2] Even if the incinerator is shut down, it is assumed that the capital recovery charges continue. At 16%/yr this is $9,600. This charge is added to the three independent technologies.

* These annual costs include the cost of reheating the plume to initial discharge temperature to increase buoyancy. If reheating is neglected, both figures are reduced by $7,100. Figures in parentheses are less reheat.

If exercised, the option to cease operations could have a profound localized impact. Significant payroll would be lost, as would other community incomes. Table E.2 shows estimated losses. The figures in Table E.2 are not additive directly, and must be viewed as separate impacts.

TABLE E.2

Economic Impact of Termination of Operations

	Generated Amount	Economic Impact Multiplier (2)
Lost Wages	$1,178,885/yr	$2,357,770/yr
Lost Revenue	800,000/yr	1,600,000/yr
Real Estate Tax	45,826/yr	91,652/yr
Personal Property Tax	17,052/yr	34,104/yr

Benefits derived from a reduction in emissions to that technically required by Rule 203(e)(4) are much more difficult to assess. This is due both to the already low level of emissions from the facility as well as the relatively good air quality in the Charleston area.

If enforced, existing Rule 203(e)(4) would affect approximately 3.63 tons per year of particulates. For purposes of benefit estimation, this report assumes that 100% of these emissions drop out into the Charleston area. Needless to say,

this very conservative approach would tend to overstate damages and consequent benefits estimates.

The effect on air quality was generated by using short-term mathematical techniques and scaling upward to longer term effects. This procedure tends to produce more conservative results as the sampling time increases; that is, it probably overstates ambient concentrations on a 24-hour and annual average basis. Incremental impacts of Addressograph-Multigraph's facility on air quality under two typical air stability classifications are as shown in Table E.3.

TABLE E.3

Maximum Expected Particulate Increases from R77-5

	Less than 10-Min. Sample $\mu g/m^3$	24-Hr. Sample $\mu g/m^3$	1-Yr. Sample $\mu g/m^3$
Class A Stability	1.9 - 1.2	0.51	0.189
Class D Stability	1.4 - 1.0	0.38	0.128

Because the D Stability classification is usually found in the Charleston area, this report uses the 0.128 $\mu g/m^3$ estimate as the potential increase in air quality resulting from promulgation of R77-5. Again, the assumption that the

maximum concentration point characterizes the entire Charleston area may be regarded as very conservative.

Benefits are calculated by two methods. The first method assumes that total emissions from the incinerator fall out within Charleston, and that the fallout affects the community in a manner similar to that determined for the nation as a whole.

The second methodology assumes that a given incremental deterioration in air quality will impose certain costs on society. These costs have been assessed for the Chicago area and are extrapolated to Charleston in this report. Table E.4 displays the benefits attributable to a cessation of emissions of Addressograph-Multigraph's facility as estimated by each of the above procedures.

The range of benefits ($7,702 - $1,430) found in Table E.4 is not unexpected, due to the differences in the procedures used to calculate the basis (e.g., air quality increments). The figures do, however, yield a range to which costs can be compared.

Cost/benefit analysis cannot always involve a simple subtraction of costs from benefits. Although Chapter 5 follows this approach, only the incremental costs (e.g., Table E.1, column 2) are used as a basis for comparison.

This basis of comparison is valid in that the costs associated in assessing a specific benefit are associated with additional capital outlay on the part of Addressograph-Multigraph.

TABLE E.4

Benefits of Reduced Emissions

Benefit Category	By Particulate Fallout Method $/Yr	By Incremental Air Quality Method $/Yr
Health Effects	622	1,320
Life Expectancy	--	538
Materials	264	1,242
Residential Property	543	--
Vegetation	1	1,602
Other Effects	--	--
Totals	$1,430/yr	$7,702/yr

The cost of the incinerator is a cost that was previously expended to abate emissions to the current level. The author recognizes that some persons would argue that the total costs (e.g., Table E.1, column 3) should be used to generate cost/benefit comparisons. The approach used in this report is a more accurate portrayal of actual cost/benefits.

Chapter 5 arrives at a cost/benefit analysis which determines ranges of costs to certain areas of health and welfare. Because of the relatively small impact of Addressograph-Multigraph's discharge, the impact on various sections of the

state's economy can only be approached in a generalized manner as follows.

1. Environmental Costs and Benefits: The impacts of costs and benefits can best be assessed by a review of Tables E.1 to E.4. Such costs will vary, depending on the control option utilized. Benefits received will vary depending on the net improvement to the air quality in the immediate area.

2. Economic Impact on State: The only case that would have a measurable economic effect on the community would be if Addressograph-Multigraph were to terminate operations. Such an action would result in the loss of 123 jobs. The type of product produced at the Addressograph-Multigraph facility (print paper) would not cause a measurable impact on the availability of other goods or services in Illinois.

3. Effect on Illinois Agriculture: The acceptance or rejection of Addressograph-Multigraph's proposal would have no measurable effect on Illinois agriculture.

4. Effect on Local Government: A closure of the facility would result in reduced income to the community in terms of lost tax revenue and wages paid (Table E.2). Changes in air quality due to Addressograph-Multigraph's emissions are rather small, and it is estimated that the cost to local government to mitigate the effects of such emissions will be negligible.

Chapter 1

Introduction

The purpose of this study is to determine the costs and benefits associated with proposed regulation R77-5, which amends Rule 203(e)(4) of the Air Pollution Control Regulations of the Pollution Control Board (Chapter 2). The existing rule reads in part:

> "(4) No person shall cause or allow the emission of particulate matter into the atmosphere from all other new incinerators to exceed 0.1 grams per standard cubic foot of effluent gas corrected to 12 percent carbon dioxide."

The request for amendment[1] was filed by the Addressograph-Multigraph Corporation, which owns and operates a facility for the manufacture of reproduction print paper in Charleston, Illinois. Among other unit operations, Addressograph-Multigraph disposes of liquid waste via a liquid incinerator known as a thermal destructor. As presently operated the incinerator emits particulate matter into the atmosphere in violation of Rule 203(e)(4).

Addressograph-Multigraph argues that a new rule should be

added to Chapter 2, to be known as Rule 203(e)(4)(A). The proposed rule would allow the incinerator to operate as it presently does, but would provide a mechanism whereby the emissions would be judged in compliance.

This chapter briefly highlights the motivations for the proposed change, the costs and benefits which will be considered, and the regulatory options available to the Board. Subsequent chapters will detail costs (Chapters 2 and 3), benefits (Chapter 4), and the comparisons of the two (Chapter 5).

1.1 Motivation for the Regulation

The rationale for R77-5 is rather unique in that it holds that the present regulation is not applicable to the Petitioner on the basis of mathematics rather than control technology. Petitioner argues that its present facilities meet the intent and spirit of the regulation, but due to a mathematical inequity its facility cannot meet the "letter of the law."

Rule 203(e)(4) limits particulate emissions from incinerators by setting specific grains per standard cubic foot criteria. In order to assure that dilution, by excess air, is not used as a method of circumventing the regulation, a correction factor based on 12% carbon dioxide in the effluent gas is utilized. This correction factor presupposes that the carbon content of the fuel is sufficient to produce approximately the 12% carbon dioxide level. In Petitioner's

case the material incinerated is exceedingly low in carbon content. Appendix A gives the mathematical underpinning of the 12% conversion factor, and Table 1.1 demonstrates its effect on particulate loading under varying carbon dioxide levels in the effluent stream.

TABLE 1.1

Effects of 12% Conversion Factor on Particulate Loading

(A) Actual Emissions (Rule 203[e] [4]) gr/SCF	(B) 12% Correction	(C) Carbon Dioxide % in Exhaust Gas	(D) Corrected Emissions gr/SCF
0.04	x 12 ÷	6%	0.08
0.06	x 12 ÷	5%	0.14
0.08	x 12 ÷	4%	0.24
0.0903	x 12 ÷	0.0146%	74.25
0.1	x 12 ÷	2%	0.6
0.1	x 12 ÷	12%	0.1

Rule 203 (e) (4) sets a maximum emission rate of 0.1 gr/SCF.* As can be seen from Table 1.1, all of the "actual emissions" in Column A are within the compliance level. To "correct" the actual emissions to 12% carbon dioxide, the emissions are first multiplied by the standard, 12% and then divided by the

*grains/standard cubic foot

actual carbon dioxide level in the exit air (Column C, Table 1.1). If the waste stream has the ideal 12% carbon dioxide level, the measured emissions are equal to the corrected emissions. As the carbon dioxide level decreases, the corrected emission level increases, and a violation may exist, even though total particulate emissions do not increase.

The basic motivation behind the proposed regulation is to formulate a methodology which will allow compliance with the intended grain loading, while taking into consideration the unique characteristics of the incinerated wastes.

R77-5 incorporates the following basic principles:

1. Rule 203(e)(4) would not apply to aqueous waste incinerators, which after correction to 50% excess air produce less than 1.2% carbon dioxide in the exhaust gas. Such carbon dioxide emission is limited to that resulting from the charge alone.
2. After correction to 50% excess air, the emission rate shall not exceed 0.1 grains per standard cubic foot dry basis.
3. The total charge to the incinerator shall not exceed 2000 pounds per hour.

The very nature of the proposed regulation, as well as conversations with the Illinois Environmental Protection Agency,[4] indicates that the scope of this proposal is very

narrow. It is expected that, if adopted as proposed, only a very small number of incinerators could be involved. Appendix B provides the actual amended petition for regulatory change.

In this analysis costs are defined with Addressograph-Multigraph as the point of reference. Thus, costs may be encountered in three distinct ways:

- Costs to upgrade existing environmental control equipment,
- Costs to replace existing control equipment with alternate devices,
- Costs incurred by ceasing production to meet standards.

The first method by which costs may be incurred is rather straightforward. It assumes that the present control equipment (incinerator) can be retrofitted with a tail-end cleanup device so as to meet applicable standards. The second method assumes that the emitter, either for technical or economic reasons, chooses to replace the existing incinerator and utilize an alternate technology. In that case the associated costs include not only the annual operating and maintenance cost of the new equipment, but also capital recovery charges for the new as well as for the discarded technology.

The third option incurs greatest total social cost. The cost to the emitter is obvious - the loss of his production facilities, and the associated deferred or lost capital recov-

ery mechanism. The cost to society is measured as a loss in personal income, taxes, and local expenditures.

Chapter 3 explores each of these options in detail and presents the results for the Board's consideration.

Benefits in this study are defined as the change in environmental damage which would follow from adoption of R77-5. The difficulty in performing this analysis stems from two basic facts:

- Inconclusive data base for monetization of benefits,
- Extremely low level emissions, which yield only small changes in air quality, or small amounts of fallout.

Because of these problems, this report will look at benefits from two viewpoints.

The first explores the benefits derived by a given reduction in total emissions. Benefits in the following generalized areas are approximated:

- Effects on residential property,
- Effects on materials,
- Effects on health,
- Effects on vegetation.

This analysis is based on an extrapolation of costs associated with national emission estimates.

The second approach utilizes the concept that an incremental deterioration of air quality can be associated with re-

ductions in damages and resources expended. Once again, benefits are allocated according to categories (e.g., health, materials, etc.). Using these two methodologies produces a range of benefits.

1.2 Potential Alternate Regulatory Schemes

Section 27 of the Environmental Protection Act[2] delegates authority to the Board to adopt and amend regulations for the control of pollution. Accordingly, once a proposal for regulatory change is presented to the Board, the Board has the responsibility to review that proposal, and, after adequate hearings, either adopt or reject it. The proposal need not be adopted exactly as submitted; the Board may modify the initial proposal as it deems necessary and proper. Thus the Board may follow various options in determining the ultimate form of the proposed regulation.

The first option open to the Board is to accept the proposal as submitted via the First Amended Petition to Amend.[1] This report will cover the environmental costs associated with such a decision as well as the benefits derived.

Another option is to reject the proposal outright and require Petitioner's incinerator (and others in the same class) to comply with existing Rule 203(e)(4).

The Board could also elect to extend the scope of the proposed examption to all incinerators which burn low carbon wastes, regardless of the form or amount of wastes incinerated.

This could be accomplished by setting a standard for low carbon wastes which is keyed to a weight of emission per weight of material incinerated. Such an option would be essentially patterned after a process weight scale as utilized in Rule 203(a) and (b) of its Air Pollution Control Regulations.

The above are but a few of the possible options available to the Board. In following chapters of this report the technical and economic considerations of each viable option will be discussed. Additionally, the environmental consequences of the various options will be covered. No attempt will be made to select one option as favorable over another; that is clearly the responsibility of the Board. However, this report will point out specific technical, economic, or environmental pitfalls of an option as the author perceives them.

Chapter 2

Technical Considerations

Before discussing the costs and benefits of the proposed rule change, some general background information merits attention. Proposed regulation R77-5 was filed on March 3, 1977, and amended on August 30 of that year. The proposed change would affect only one incinerator at Petitioner's facilities.

2.1 Overview of Addressograph-Multigraph's Emissions

Addressograph-Multigraph is located in Charleston, Illinois, and manufactures reproduction print paper for the engineering industry. In its production process various liquid wastes are generated which feed into an incinerator. The only byproduct (excluding emissions to the atmosphere) of such incineration is a small amount of sludge which can be disposed of by landfilling.

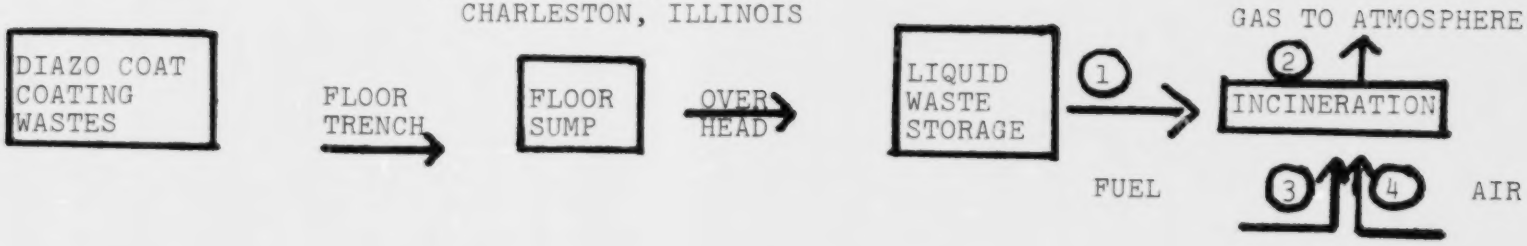
The inflow and outflow of materials to the incinerator are shown in Figure 2.1. Sample feedstock characteristics are shown in Table 2.1.

Emissions from Addressograph's incinerator are estimated at 1.163 lbs/hr. or .09034 gr/SCF of stack gas. These emission rates come from stack tests conducted for Addressograph-Multigraph by Particle Data Laboratories. Results appear

FIGURE 2.1

FLOW DIAGRAM AND MATERIAL BALANCE
LIQUID WASTE INCINERATION

CHARLES BRUNING COMPANY
CHARLESTON, ILLINOIS



STREAM NAME	STREAM NO.	FLOW	WATER	COMBUSTIBLE ORGANICS	NON-COMBUSTIBLE INORGANICS	CO_2
DIAZO COATING WASTE	1	4000GPD 33,360 #/day	3980 GPD 33,200 #/day	151#/day	21#/day	--
EFFLUENT COMBUSTION GAS	2	1680 SCFM	682 SCFM 47,600 #/day	--	21#/day 0.061#/day (1)	113 SCFM 6.7%
FUEL	3	5650 SCFM	--	--	--	--
AIR TOTAL	4	1013 SCM	--	--	--	--

(1) Not corrected for CO_2

TABLE 2.1

WASTE CHARACTERISTICS
SIMULATED DIAZO WASTE

PARAMETER	SETTLED SAMPLE		TOTAL SAMPLE	
	SUPERNATANT mg/l	SLUDGE mg/l	mg/l	lbs/day
Suspended Solids	2,130	283,000	18,800	71
Volatile Suspended Solids	1,690	264,000	17,400	66
Dissolved Solids	15,300	--	15,300	58
Volatile Dissolved Solids	12,400	--	12,400	47
Total Chemical Oxygen Demand (TCOD)	17,400	345,000	37,100	140
Soluble Chemical Oxygen Demand (FCOD)	16,450	--	16,500	62
Ammonia-Nitrogen	1.8	65.8	5.59	.021
Total Nitrogen	1,330	670	1,290	4.8
Sulfate	350	--	350	1.3
Soluble Total Organic Carbon (FTOC)	7,850	--	--	
Soluble Total Inorganic Carbon (FTIC)	0	--	--	
pH	2.28	--	2.28	
Phenols	0.73	--	0.73	.003
Aluminum	19	77	22	.003
Zinc	840	1,720	893	3.4
Tin	335	<0.02	31.5	.12

NOTE: Concentrations representative of daily waste stream volume of 450 gallons

below:

Repetition	Measured gr/SCF
1	0.07861
2	0.09791
3	0.09451
Average	0.09034

These figures do not show correction for 12% carbon dioxide. The average combustible carbon in Addressograph's waste is 440 ppm, which at the amount of excess air used by Addressograph, translates to a 0.0146% carbon dioxide in the exhaust gas. It is, of course, possible to correct the measured particulate discharge level to any factor, and Table 2.2 shows the results at various corrections for the sake of comparison.

Table 2.2 illustrates that the methodology of correction can have a profound effect on the emission rate which is used to compare against the standard (0.1gr/SCF at 12% carbon dioxide). When comparing Addressograph's emissions as corrected for 12% carbon dioxide to the standard, enormous violations apparently occur. On the other hand, corrections to 50% excess air (as proposed in R77-5) shows the emissions to be well within the regulatory requirements.

Regarding the potential effect on the environment, the only significant number is the actual amount of particulates emitted to the atmosphere, in Addressograph's case an average of 1.163 lbs/hr. For assessment of costs/benefits in the following chapters, actual emissions will be utilized.

TABLE 2.2

Effect of Methodology of Correction on Emission Rate

Test #	gr/SCF Actual Measure	gr/SCF Corrected to 12% Carbon Dioxide	gr/SCF Corrected to 50% Excess Air	#/hr Weight Load
1	0.07861	64.6	0.06037	1.042
2	0.09791	80.5	0.07639	1.286
3	0.09451	77.7	0.07345	1.160
Average	0.09034	74.3	0.07007	1.163

2.2 Selection of Alternates To Be Considered

The above discussion relates to a site-specific case (Addressograph), but R77-5 could conceivably be amended to cover many more sources. It is important, therefore, to try to estimate the number of sources which might be affected by the proposed regulation or variations thereto.

1. Adoption of Regulation as Proposed:

In its presentation to the Board, Addressograph summarized a survey of incinerator vendors. The intent was to determine how many liquid incinerators exist in Illinois which could be

affected by the proposed rule change. The results of that survey can best be summarized in the following excerpt from testimony:

> "Consequently, mostly all of these incinerator installations in Illinois have been reported by their manufacturers as being in compliance. Thus we have been unable to find any other installations in Illinois which clearly would be affected by our regulatory change."[3]

While it is not certain that there are no other facilities which would be affected by the proposed regulation, it is fairly clear that at the most only a very few facilities would be affected.[4] For the sake of this report, it will be assumed that only the Addressograph facility would be affected. Costs and benefits are calculated accordingly.

If the Board were to adopt Addressograph-Multigraph's proposal, no additional environmental control equipment would be required. The wording of the proposed regulation is such that the incinerator in question would be deemed in compliance.

2. Rejection of the Proposal:

As was the case above, it was assumed in this study that outright rejection of R77-5 would affect only one source. Should this action come to pass, Addressograph would have the following options: meeting the present regulation, changing disposal technology to comply under a different rule, or ceas-

ing its discharges.

To meet the present rule, Petitioner would have to reduce its emissions from a corrected value of 74.3 gr/SCF (Table 2.2) to 0.1 gr/SCF. This would require a reduction of measured emissions from the present level of 0.09034 gr/SCF to a measured level of 0.00012 gr/SCF. Assuming a lineal lb./hr. load reduction, actual emissions would have to decline from 1.163 lbs./hr to 0.0015 lbs./hr. Needless to say, a reduction requirement of this magnitude would require the discharger to investigate emission control equipment for the present incinerator.

A second option would be to use an alternate technology. Several are listed below:

1. Reverse osmosis
2. Spray drying
3. Evaporation
4. Waste solidification
5. Trucking off-site, contract disposal

It is obvious that the use of any of these methods would relieve Addressograph from compliance with an incinerator-based regulation. In certain of the cases particulate emissions would totally cease to exist. Undoubtedly other regulations would come into force (e.g., for reverse osmosis, disposal of purge would be controlled), as would different environmental impacts. A close look at such potential impacts is beyond the scope of this report. Suffice it to say that each technology has its associated environmental concerns in addition to technological and economic impacts.

The third option available to Addressograph, should the Board opt to reject the proposal, would be to cease operations. While this would obviously halt emissions, severe economic consequences would befall Addressograph and the surrounding community. The economic costs of such an option are explored later in this report.

3. Adoption of an Expanded Regulation:

Although virtually no evidence was introduced at the technical hearings regarding the effect of a more sweeping regulation, the Board could conceivably opt for this approach. Such a decision might be based on the theory that the mathematical inequity described previously applies to all incinerators which burn wastes of a low carbon content. Moreover, it would apply to solid as well as liquid wastes, and to any volume of wastes consumed.

Very little data exist as to the number of incinerators in Illinois which could conceivably fall under an expanded regulation. This fact is best documented by records of the Illinois Environmental Protection Agency, which show no violations or requests for variances owing to low carbon waste problems.[4]

In any event, this report assumes that if such cases did exist, the results would be similar in effect to the proposed regulation on Addressograph. This means that the discharge would have been in compliance with Rule 203(e)(4) had the carbon content of the fuel been such as to yield an approx-

imate carbon dioxide value of 12%. In the simplest terms, then, the effect of such a regulation would be to allow low carbon waste incinerators to emit approximately the same particulate level as "high" carbon waste materials. Should the Board elect to adopt a regulation based on "pounds of particulate per weight of exhaust gas," the results would be the same regardless of the carbon dioxide content of the effluent stream. A regulation could conceivably be fashioned which would equitably relate the weight of particulate/weight gas stream concept directly to the 12% carbon dioxide corrected concept. If such were the case, the effects of the regulation would be to compensate for low carbon waste streams but not increase the overall discharge levels. A similar case can be made for the pending regulatory change, which uses 50% excess air as the correction factor.

2.3 Summary of Possible Alternatives

The above three options are among those which may be considered by the Board. Inasmuch as Option #3 lacks sufficient data and basis for examination, the effects of such an expanded regulation will not be evaluated. Options 1 and 2, representing the simple extremes of Board action, will receive detailed consideration.

Chapter 3

Costs of Pollution Control Options

Should Addressograph-Multigraph be forced to comply with existing regulations, its options, as mentioned in Chapter 2, include control of the present incinerator, utilization of alternate technologies, or cessation of operations. This chapter will explore the costs of the various options in detail.

3.1 Control of Present Incinerator

Addressograph currently disposes of its waste by means of incineration, as depicted in Figure 2.1. However, because of the unique nature of the firm's waste, the corrected concentration of particulate is 74.3 gr/SCF, against a required level of 0.1 gr/SCF. Thus, in order to comply with the 0.1 gr/SCF limit, a control device of approximately 99.9% efficiency would have to be retrofitted to the incinerator.

Table 3.1 details the type of devices which are available, along with their anticipated efficiency ranges. It is clear that the needed efficiency would lie at the extreme high end of the illustrated range.

The three technologies which have a potential to meet the required efficiency are baghouses (fabric filters), electrostatic precipitators, and scrubbers. The costs of each of these options will now be examined.

TABLE 3.1

Collection Efficiencies for Municipal Incineration Particulate Control Systems

Device	% Efficiency
Settling Chamber	0-30
Settling Chamber & Water Spray	30-60
Wetted Baffles	60
Mechanical Collector	30-80
Scrubber	80-95+
Electrostatic Precipitators	90-99+
Baghouses	97-99+

1. Baghouses:

Equations to estimate the capital and operating costs of baghouses have recently been developed by Bubenick[5] as an outgrowth of detailed work by Fraser and Foley.[6] The basic capital cost items have been itemized as follows:

(a)	Basic collector	$= 1.20(G/R)^{1.07} - B(G/R)$
(b)	Bag cost	$= B(G/R)$
(c)	Mechanical components	$= 0.20(a)$
(d)	Electrical components	$= 0.20(a)$
(e)	Insulation	$= 0.45(a)$
(f)	Structural supports	$= 0.12(a)$
(g)	Tax and freight	$= 0.08(a \text{ to } f - e)$
(h)	Engineering	$= 0.07 \ (a \text{ to } f)$
(i)	Erection	$= 168(G/R).^{55}$
(j)	Contingencies	$= 0.1 \ (a \text{ to } i)$

These factors reflect late 1976 cost estimates, and an overall equation would take the final form:

$$Ct = 3.04\left(G/R\right) 1.07 - 1.23\ (G/R)\ B + 185\ (G/R)^{.55} \quad (1)$$

where

Ct = Total Capital Costs, $.

G = Gas flow, actual cubic feet per minute (ACFM).

R = Air to Cloth Ratio for Bags, ft^3 / ft^2.

B = Cost of Bags, $.

Addressograph has reported that the total gas flow needing treatment would be approximately 2362 SCFM. Assuming an outlet temperature of 1600°F and one atmosphere pressure, the actual cubic feet per minute would be 10,578. The air to cloth ratio (R) was set at 2 and a typical bag cost at $\$0.50/ft^2$. When these figures are inserted into equation (1), the result is:

$$Ct = \$46,703.$$

This capital cost applies to a rather simple installation and should be taken as a lower bound. The lower bound estimate is based on lack of retrofit problems and ease of erection.

Operating costs are dependent upon capital recovery costs, bag life, power costs, maintenance and operating labor charges as follows:

(a) Labor and Maintenance = 0.05 (ct)

(b) Bags $= \frac{B(G/R)}{Lo}$

(c) Power $= 1.58(G)\left(\left[.93(R\cdot 1.1)^{1.5}\right]+1\right)Pc$

(d) Administration = .1(a)

(e) Overhead = 0.1(a+b+c)

(f) Capital Charges = 0.16(ct)

An overall equation would take the following form:

$$At = 0.22\ Ct + 1.1\frac{B}{Lo}\ \frac{G}{R} + 1.738(G)\ (Pc)\ (.93(1.1R)^{1.5}+1)L$$

The following terms apply:

At = Annual Operating Costs, $/yr. (including capital charges.

B = Bag Cost, $/ft^2

Lo = Life of Bags, yrs.

Pc = Power Charge, $/kwhr.

L = Load Factor, %.

Power charges are assumed to be $0.0185/kwhr, bag life is set at one year, and L = 90%.

Applying the annual cost equation to Addressograph-Multigraph's facility:

At = Annual costs including capital recovery = $14,419/yr.

At - Capital Recovery =$6,946 /yr.

2. Electrostatic Precipitators:

Bubenick[5] also considered the costs of electrostatic precipitators. It should be noted that such equipment is not generally applied to low air flows as experienced by Addressograph-Multigraph. The equations and costs calculated below are intended to give the reader ball park estimates for the sake of comparison. The use of an electrostatic precipitator on the gas stream under question could only be considered after in-depth consultation with an equipment vendor.

Basic capital costs have been itemized as follows:

(a)	Collector	$= 18\ (F)^{.89}$
(b)	Accessories	$= 0.15(a)$
(c)	Structural	$= 0.99(F)^{.97}$
(d)	Tax and freight	$= 0.08\ (a+b+c)$
(e)	Engineering	$= 0.05(a \text{ to } c)$
(f)	Installation	$= 14.2\ (F)^{.91}$
(g)	Contingencies	$= 0.05\ (a \text{ to } f)$

An overall equation would take the following form:

$$Ct = 24.42\ [F]^{.89} + 1.18\ (F)^{.97} = 14.91(F)^{.91}$$

The following terms apply:

Ct = Total Capital Costs, $.

$F = \frac{(SCA)\ (G)}{1000}$

SCA = Specific Collection Area, $ft^2/1000\ \frac{ft^3}{m}$

G = Actual Cubic Feet per Minute, $ft^3/min.$

From the literature* a factor of 500 for SCA is applied. Once again the estimated flow rate is 10,578 ACFM. Utilizing the above on Addressograph-Multigraph's facility, the result is:

$$Ct = \$91,577.$$

Operating costs are again dependent on capital recovery, power, labor, maintenance, and overheads as follows:

(a) Labor $= 26.8\ (G)^{.4}$

(b) Maintenance $= 0.05\ (G)$

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*APCA, Annual Conference Paper 77-14.1, Paper 77-14.2. Proc. 4th Annual Industrial Air Pollution Control Conference, Greco, TVA.

(c) Power = 8.76 (F)(Pi)(Pc)(L)

(d) Administration = 0.1 (a)

(e) Overhead = 0.1 (a + b + c)

(f) Capital charges = 0.16 (Ct)

An overall equation would take the following form:

$$At = 32.2(G)^{.4} + .055(G) = 9.64(F)(Pi)(Pc)(L) + .16\ Ct$$

The following terms apply:

At = Total Annual Costs, $/yr.

Pi = Power Input, wts/ft^2

Pc = Power Charge, $/kwh

L = Load Factor

For Addressograph-Multigraph's facility, we will assume power input at 1.5 wts/ft^2, Pc at $.0185/kwh, and a 100% load factor.

Applying the annual cost equation to Addressograph-Multigraph's facility:

At = Annual costs including capital recovery = $17,960/yr.

At - Capital Recovery = $3307/yr.

3. Venturi Scrubbers:

Pedco Environmental[7] has undertaken studies of the cost of particulate control devices as an add-on when power plants use sulphur dioxide scrubbing. Because the following equation is sized for generally large installations, its results must be regarded as a lower bound estimate of costs.

Basic capital costs including installation have been itemized as follows:

(a)	Venturi Costs	$2.205(G)$
(b)	Tanks	$0.011G + 31.25\sqrt{G}$
(c)	Pumps & Lines	$0.056G + 20{,}000$
(d)	Indirects	$0.46\ (a + b + c)$
(e)	Contingency	$0.2\ (a \text{ to } d)$

An overall equation would take the following form:

$$Ct = 3.98(g) + 54.76\sqrt{G} + 35040$$

where:

Ct = Total Capital Costs

G = Actual Cubic Feet per Minute, $ft^3/min.$

Applying the equation to Addressograph-Multigraph's facility:

$$Ct = \$82,772$$

Annual costs are dependent on the following:

(a) Utilities = 1.2(G)(L)

(b) Labor and Maintenance = 0.05 Ct

(c) Overhead = 0.1(a + b)

(d) Capital Costs = 0.16 Ct

An overall equation would take the following form:

$$At = .215\ Ct + 1.3(G)(L)$$

Applying the equation to Addressograph-Multigraph's facility:

At = Annual costs including capital recovery = \$30,172

At - Capital Recovery = \$16,928/yr.

The above analysis yields costs for the three basic retrofit options which may be used to control the existing incinerator. Table 3.2 summarizes these costs. Annual operating costs do not include capital recovery charges which represent a significant sum. Total annual costs include the value for capital recovery.

TABLE 3.2

Incineration Control Options

	Capital Costs	Annual Operating Costs	Total Annual Costs
Baghouse	$46,703	$6,946	$14,419
Venturi	82,772	16,928 (9,828)*	30,172 (23,072)*
Electrostatic Precipitators	91,557	3,307	17,960

3.2 Alternate Technologies

It is possible that Addressograph-Multigraph could utilize alternate disposal methods for their wastes. This option would entail writing off the cost of the present incinerator

*These annual costs include the cost of reheating the plume to initial discharge temperature to increase buoyancy. If reheating is neglected, both figures are reduced by $7,100. Figures in parentheses are less reheat.

and utilizing a completely new approach. This section investigates the costs and applicability of various techniques.

1. Reverse Osmosis:

A potential method of disposing of the subject waste is reverse osmosis. Reverse osmosis is a membrane permeation process, whereby relatively pure water (or other solvent) is separated from a less pure solution. The solution is passed over the surface of an appropriate semipermeable membrane at a pressure in excess of the effective osmatic pressure of the feed solution. The permeating liquid is collected as the product, and the concentrated feed solution is generally discarded. One of the constraints on such a system is that the level of separation is, in part, dictated by the osmatic pressure of the feed solution. Thus it becomes increasingly difficult and expensive to "reduce" the volume of the concentrated stream (that stream containing the objectionable material).

Addressograph has investigated the use of reverse osmosis on two separate occasions.[8] The first set of tests was conducted by the Ray Pak Inc. R/O System Division of Ropak. Tests were only marginally successful, and then only after a coagulation technique was used to remove suspended particles. Without such separation the membranes blinded (restricted flow), resulting in a substantial loss of efficiency.

A second set of tests was conducted with the Fluid Science Division of Universal Oil Products. Drawing on previous ex-

perience, the firm investigated pretreatment with ultra-filtration and chemical coagulation to reduce membrane buildup. Although the tests proved promising, the problem of concentrated stream disposal still remained.

On the basis of these experiments it appears that a three-unit process would be required (i.e., pretreatment, reverse osmosis, disposal of sludge) to successfully utilize reverse osmosis. However, additional research and development would surely be required before any commitment of resources could be made.

Because of the above, it is impossible to pinpoint exact potential costs of this technology as applied to Addressograph-Multigraph's waste stream. Order of magnitude costs can, however, be obtained. This is done through a literature search of postulated costs for reverse osmosis as applied to other processes.[9, 10, 11, 12] As anticipated, most reverse osmosis applications are for flows far in excess of 4000 gpd. Figures 3.1 and 3.2 show the anticipated capital and operating costs for reverse osmosis at smaller flow rates. As applied to Addressograph-Multigraph's waste, the expected cost would be:

Capital Costs	=	$90,000
Operating & Maintenance Costs*	=	$9,360/yr

*Operating and maintenance costs are extrapolated from Figure 3.2; $9/1000 gal. x 4000 $\frac{\text{gal.}}{\text{day}}$ x 260 $\frac{\text{days}}{\text{yr.}}$; capital recovery at 0.16 (Ct).

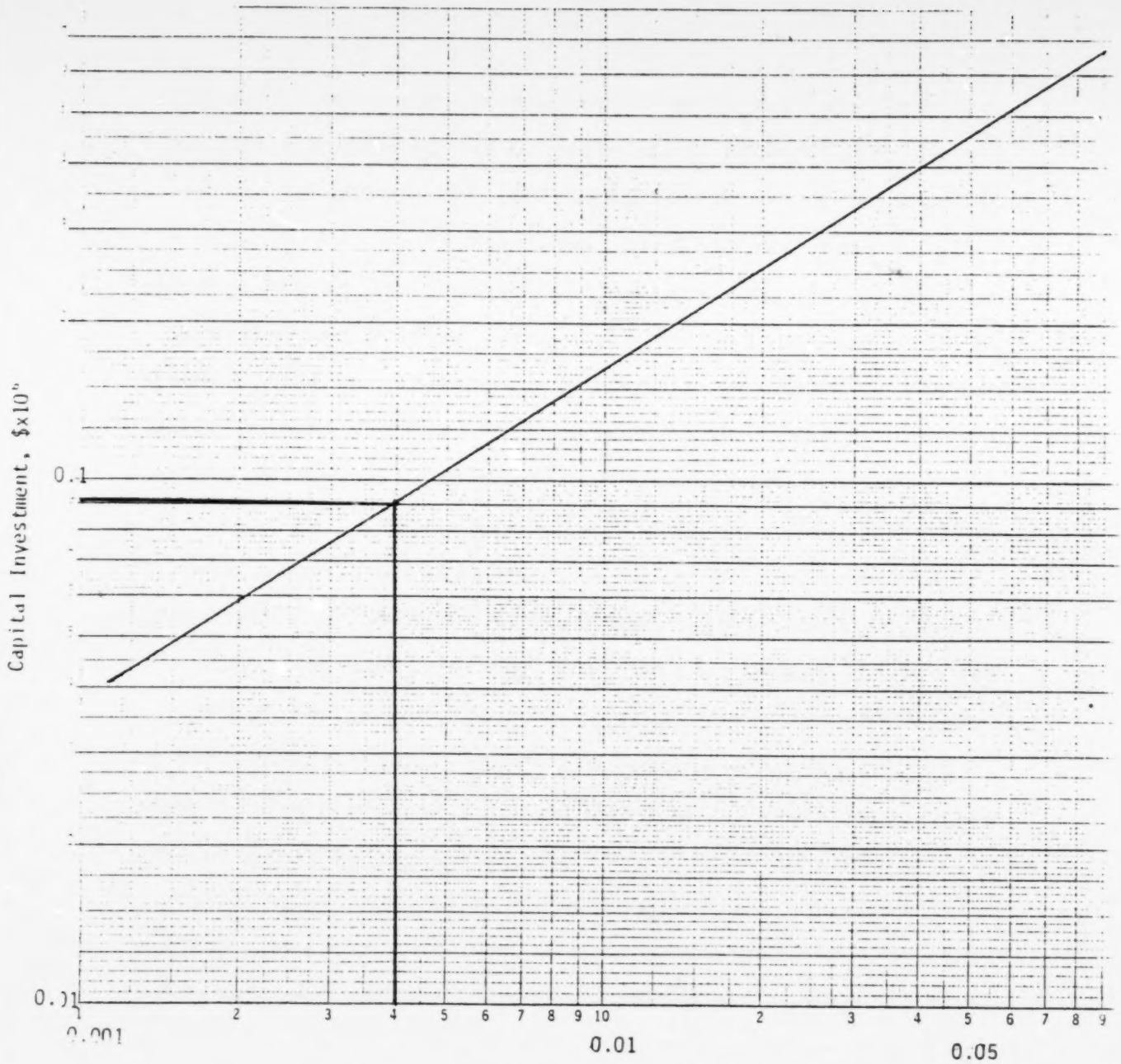

Figure 3.1

REVERSE OSMOSIS CAPITAL INVESTMENT COST,
1977 PRICES

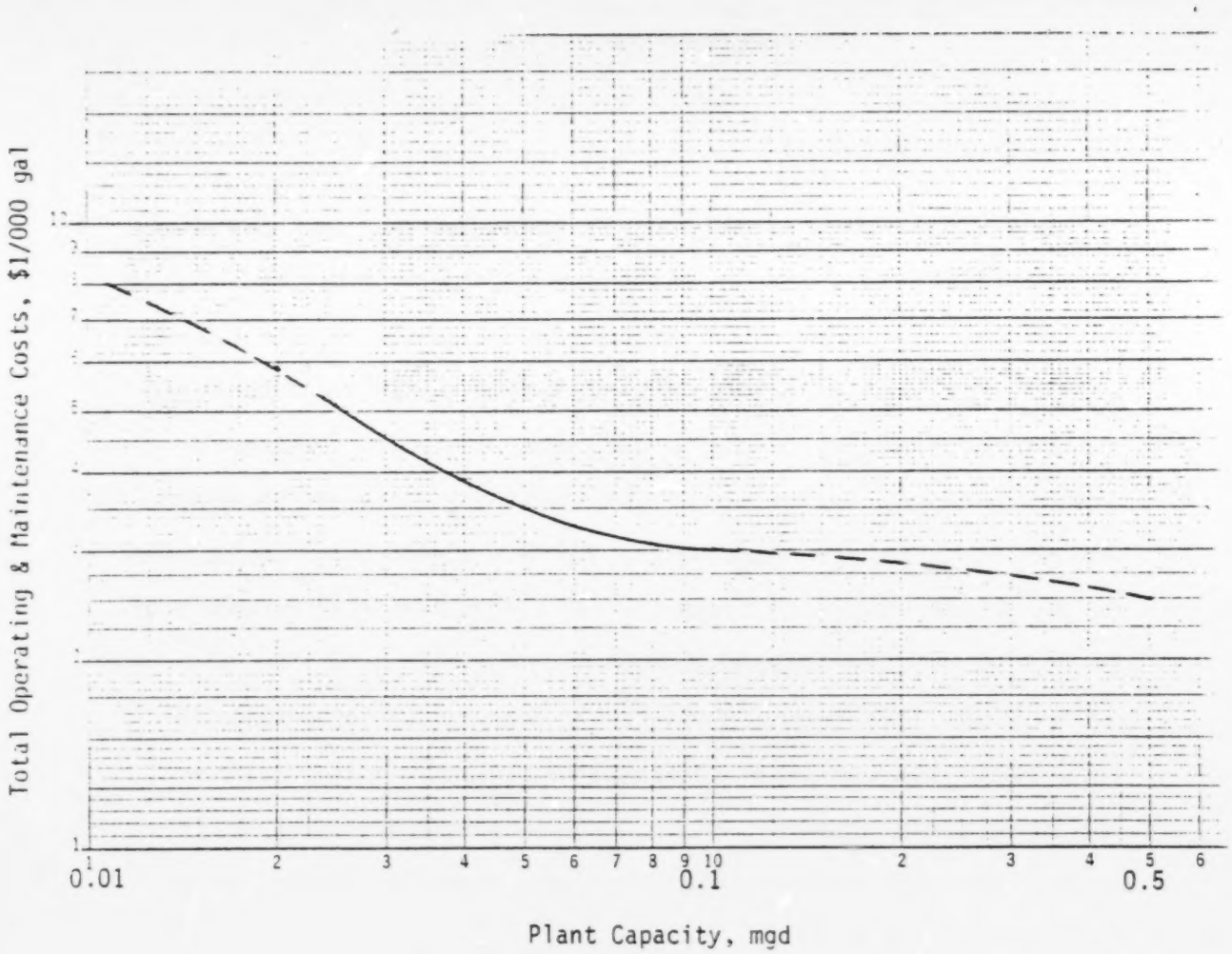

Figure 3.2

REVERSE OSMOSIS OPERATING AND MAINTENANCE COSTS
FOR SMALL FLOWS, 1977 PRICES

Operating & Maintenance & Capital Recovery = $23,760/yr

2. Contract Disposal:

Another control possibility exists which was not discussed by Addressograph in their testimony to the Board. Under this option the company would contract for disposal of the waste stream. By such an action, the material would be shipped to a licensed waste handler for ultimate disposal. Addressograph would pay for disposal but would not have to purchase or operate disposal equipment. There are numerous facilities in the state which are licensed by the Illinois Environmental Protection Agency to accept such waste.

Although this report does not intend to go into full detail as to the possible problems with handling the volumes and type of waste produced by Addressograph-Multigraph, it is apparent that such waste would not pose particular problems.[13]

The costs of such an operation are estimated to range between 4-12 cents/gal. of material disposed. This does not include handling, which has been estimated at 12-16 cents/ton/mile, or about 3 cents/gal. disposed.[13] Addressograph-Multigraph estimates the total cost of contract disposal at 13.2 cents/gal.[14] At 4000 gal/day, 260 days/yr., costs for this option would be:

	at 13.2 cents/gal.	at 7 cents/gal.
Capital Costs	- 0 -	- 0 -
Operations	$137,280/yr*	$72,800/yr

3. Miscellaneous Technologies:

Addressograph-Multigraph has investigated other technologies for disposal of their waste. All of them were deemed unsuitable for their needs for various reasons. A brief description of efforts made by Addressograph-Multigraph follows.

Waste Solidification Process: An attempt was made to produce a solidified product by adding chemical fixatives. This is similar technology to that offered for the fixation of scrubber sludge. The vendor in question claimed that the phenol concentration of the waste would have to be reduced prior to fixation (although Addressograph's independent analysis showed negligible phenol concentrations). Addressograph concluded that the vendor was not seriously interested in pursuing this option, and investigation was terminated.

Evaporation: Attempts were made with two vendors to investigate evaporation as a technique to dissipate the waste stream. In both cases the problem of potential fouling of

*Assumes adequate storage and loading facilities are on site.

the equipment was raised. Neither vendor would guarantee that the equipment could be utilized with acceptable efficiency, and the concept was abandoned.

Solar evaporation: An outdoor evaporation pond was considered. However, the precipitation/evaporation ratio in the Charleston area was found to be approximately 1.0. Thus the result would be no net loss in liquid. Additionally, freezing conditions during the winter would hamper evaporation. This concept was also abandoned.

3.3 Cessation of Operation as a Compliance Method

Should the Pollution Control Board reject R77-5, Addressograph-Multigraph could close the Charleston plant.

Closing of the plant would impose economic costs on the employees, the tax base and general economy of the area, and indirectly on the Illinois economy. The purpose of this section is to evaluate the costs associated with the closing of the Addressograph-Multigraph facility.

Effects on Employment:

Addressograph-Multigraph is located in Charleston, Illinois, in an industrial center on the north side of the city. Figure 3.3 pinpoints the exact location of the facility as well as distances from key locations.

Charleston is located in Coles County, and has a popula-

tion of 16,421. The city falls within the Mattoon-Charleston labor area, which is defined in part as follows:

In 1975 total estimated population for the area was 58,000, of whom about 35,000 live in the two principal cities of Charleston and Mattoon.

The civilian labor force includes about 45.8 percent of the total population.

State and local educational institutions are the major employers, with trades and services following in the non-factory sector. About 30 percent of nonagricultural employment is attributed to manufacturing, with electrical machinery the largest industrial group, followed by non-electrical machinery, printing and publishing, and fabricated metals.[15]

According to Labor Area Trends,

> "Nearly all of the workers who reside in the two counties also work in the area. Out commuters outnumber in commuters by only a few percentage points. As a result, the economic patterns of nearby counties have little effect on the Mattoon-Charleston area economy. The area is described as having moderate unemployment, according to federal standards, except for parts of calendar year 1975 when both total unemployed and the rate were slightly above the moderate level."[15]

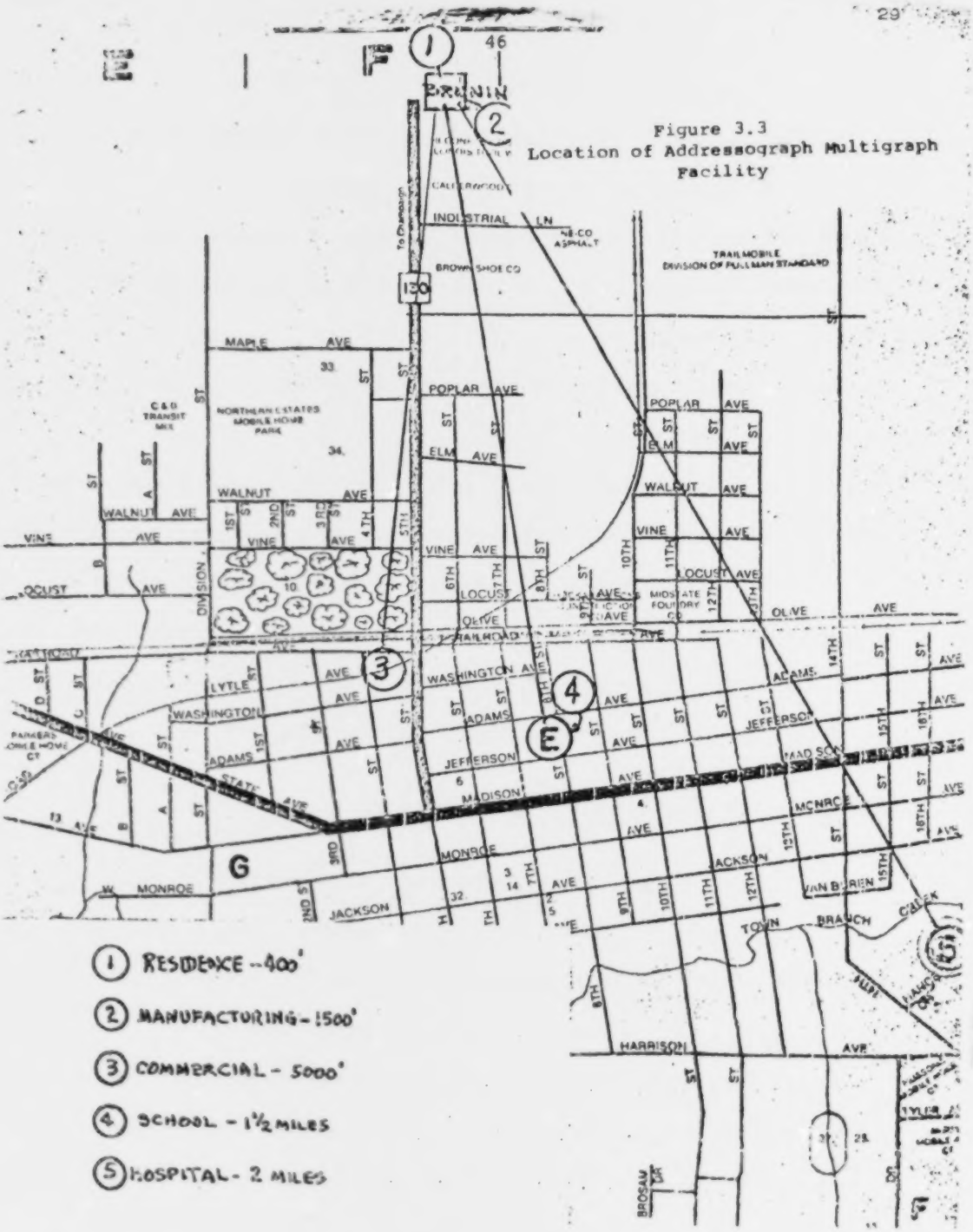

Figure 3.3
Location of Addressograph Multigraph Facility

Unemployment in the areas is shown in Table 3.3.

The outlook for area labor is recorded by the Department of Labor as follows:[15]

> "AREA LABOR SUPPLY AND DEMAND
>
> Except for some specific job openings the labor supply far exceeds the demand in the five county area. This has been the rule all during the past two years. Nearly all job openings received by the local Job Service office in Mattoon can be filled in a short time. Barriers to employment on the part of some applicants include lack of transportation, physical handicaps, prison records, etc."

In short, although unemployment in the area is expected to decline, the supply of labor will continue to exceed demand. These statistics indicate that persons becoming unemployed would take longer than average to become fully employed again. Additionally, due to the nature of the job market in the area, should a large number of persons become unemployed, they would most likely have to look for employment outside of the Mattoon-Charleston area.

The Addressograph-Multigraph facility presently employs 123 persons. Projections call for a possible increase of from 10-15% or 12-19 persons. Although this is a relatively small number of persons for a manufacturing plant, Addresso-

TABLE 3.3

CIVILIAN LABOR FORCE, EMPLOYMENT, AND UNEMPLOYMENT [1]
(COLES AND CUMBERLAND COUNTIES)
MATTOON AREA

ACTUAL DATA

Item	Number of Workers			Net Change From			% Change From		
	July[2] 1977	June 1977	May 1977	July 1976	June 1977	May 1977	July 1976	June 1977	May 1977	July 1976
Civilian Labor Force	28,675	29,225	30,200	30,250	-550	-1,525	-1,525	-1.9	-5.1	-5.2
Unemployment	1,325	1,400	1,250	1,650	- 75	+ 75	- 325	-5.4	+6.0	-19.7
Unemployment Rate	4.6	4.8	4.2	5.5						
Employment	27,350	27,825	28,950	28,600	-475	-1,600	-1,250	-1.8	-5.5	-4.4

[1] Workers counted by place of residence.
[2] Preliminary data.

graph-Multigraph provides employment for about 1/2 of one percent of the total civilian labor force in the Charleston-Mattoon area. Should all of these persons lose their jobs, the instantaneous unemployment rate would jump from 4.6% to 5.0% (basis July 1977).

The total payroll for Addressograph-Multigraph was $1,178,885 in 1976. This equates to an average pay/employee of $9,584.43. The worst case assumption would be that all of these 123 persons would not be able to find new employment, and that revenue would thus be lost to the community. In such a case a total lost wages in the first year would be $1,178,885 times a multiplier. A reasonable multiplier for an area similar to Charleston would be 2.0. Multipliers of 2 have been used in many economic analysis. Noteably IIEQ Doc #77/05. Multipliers are used to indicate that for every job directly affected, additional jobs are induely affected and thus the economic impact of lost wages would be 1,178,885 x 2 or $2,357,770/yr.

In addition to the impact of wages lost, an additional effect on the community would be the loss of revenue accrued from local purchases. The Addressograph-Multigraph facility spent $800,000 among 73 suppliers in the Charleston area for local commodities. Once again assuming the multiplier effect of 2, an impact of $,600,00/ yr would accrue.

Yet another loss to the community would be taxes paid by the corporation. In fiscal 1977 the Charleston plant paid taxes as follows:

Real Estate	$45,826
Personal Property	$17,052

Obviously, income taxes, both federal and state, were paid. Addressograph-Multigraph's accounting procedure includes the Charleston plant in the total corporate profit and loss statement, and thus exact figures on income taxes are not available.

It is important to note that the numbers generated above are not additive. They represent different and discrete potential losses to various segments of the economy. For example, lost wages impact the individual much more severely than the entire community, while lost property tax is a strain to the community as a whole more than to any one individual.

It should also be noted that the figures generated are worst case estimates. For example, if the facility were to close and the employees were laid off, the loss in wages per year per employee would be $9,584. This assumes that the employee is without work forever. Two points should be made:

First, if the employee finds work immediately at an equivalent wage, he suffers no economic loss (assume no loss in benefits).

Second, if he does not find work, the community suffers the additional loss due to an outflow of capital for unemployment compensation. One could also argue that the payment of unemployment compensation mitigates the blow of economic impact, because that money goes back into the economy.

This brief discussion is intended to demonstrate that there are significant economic impacts resulting from closure of a facility. Dollar values generated should be viewed as

an average rather than an absolute value. Table 3.4 details the possible losses accrued.

TABLE 3.4

Economic Impact of Termination of Operations

	Direct Impact	Total Indirect Impact
Lost Wages	$1,178,885/yr	$2,357,770/yr
Lost Revenue	800,000/yr	1,600,000/yr
Real Estate Tax	45,826/yr	91,652/yr
Personal Property Tax	17,052/yr	34,104/yr

3.4 Option Selection Criteria

As mentioned in Chapter 2, should the Board reject Addressograph-Multigraph's petition, a decision to control to meet the present regulation or curtail operations would have to be made. Such a decision would be made by Addressograph-Multigraph's management, based presumably on the additional costs imposed by pollution control. These costs would undoubtedly be weighed against the profitability of the plant as well as other factors.

The Charleston facility produces 19.6% of the national market for Diazo-coated print paper and tracing media. Net sales from the facility were approximately $11,000,000 in fiscal

1977. Of the various costs of doing business, Addressograph-Multigraph estimates that liquid waste disposal by incineration costs approximately 10.5 cents/gal. or $109,200/yr. It is assumed that this figure includes the cost of capital at about 16%/yr, based on an initial investment of $60,000 for the incinerator.[8]

Table 3.5 details the costs of the various control options and the new capital and annual cost outlays, should incineration be terminated or supplemented by gas cleanup.

While it would seem that elimination of incineration and installation of a reverse osmosis unit would be the lowest cost option, two points should be made. First, the reverse osmosis technique has not been proven successful on Addressograph-Multigraph's waste stream. Secondly, the problems of disposal of the highly concentrated brine stream have not been adequately addressed.

If a low-cost vendor for contract disposal could be found, this option could be economically superior. Again two points should be made. First, the question of liability remains. While the contract vendor theoretically assumes liability for his environmental action, the language of the Environmental Protection Act (i.e., "cause or allow pollution") raises the question of the ultimate responsibility of Addressograph-Multigraph. Secondly, a complete assessment of the environmental problems of disposing of Addressograph-Multigraph's particular wastes in a liquid landfill have not been adequately ad-

TABLE 3.5

Costs of Various Control Options

	Initial Capital $	Incremental Annual Costs $	Total Annual Costs $
Incineration	60,000	109,200	109,200
Baghouse[1]	46,703	14,419	123,619
Venturi Scrubber[1]	82,772	30,172(23,072)*	139,372(132,272)*
Electrostatic Precipitator[1]	91,577	17,960	127,160
Reverse Osmosis[2]	90,000	23,760	33,360
Contract Disposal[2] (High)	- 0 -	137,280	146,880
Contract Disposal[2] (Low)	- 0 -	72,800	84,200

[1] These three options can only be run in conjunction with the incinerator. Therefore, the last column (Total Annual Costs) includes the cost of operating the incinerator ($109,200) and the cost of running the retrofit option.

[2] Even if the incinerator is shut down, it is assumed that the capital recovery charges continue. At 16%/yr this is $9,600. This charge is added to the three independent technologies.

* These annual costs include the cost of reheating the plume to initial discharge temperature to increase buoyancy. If reheating is neglected, both figures are reduced by $7,100. Figures in parentheses are less reheat.

dressed. Should a contract vendor simply mix Addressograph-Multigraph's waste with other wastes and then incinerate the total, it is highly conceivable that the total particulate load would be equal to or higher than direct incineration by Addressograph-Multigraph. This is due to the fact that the particulate effluent from Addressograph-Multigraph's incinerator is in violation due to its low carbon content, rather than its absolute weight.

In any event, should Addressograph-Multigraph be required to alter the method of disposal, it is logical to assume that they would weigh the lowest cost reliable alternative against closing of the facility. This would be contract disposal. Using the high cost disposal option, the increase in costs would be $37,680/yr. This increase is about 0.34% of sales (present disposal costs are 1.0% of sales).

Thus, in the most simplistic terms, Addressograph-Multigraph would weigh the additional costs of $37,680/yr against closing the facility.

Chapter 4

Benefits of Improved Air Quality

This chapter will evaluate and quantify the reductions in particulate emissions which would result from compliance with the present Rule 203(e)(4), as well as the environmental benefits of such reduction.

At the outset, it is important to restate the fact that the incinerator in question emits a very low volume of particulate matter, and would be in compliance but for the mathematical quirk resulting from the low carbon content of the fuel. As mentioned in Chapter 2 of this report, in order to comply with Rule 203(e), particulates would have to be reduced from an average limit of 1.163 lbs./hr to 0.0015 lbs./hr or 99.9%. For purposes of benefit estimation, it is assumed that compliance will effectively reduce emissions by 100%, or 1.163 lbs./hr. Operating 24/hr/day, 260 day/yr the total emission reduction comes to 7257 lbs./yr or 3.63 tons/yr.

4.1 Air Quality Impact of Addressograph-Multigraph's Emissions

Before attempting to determine the effect of such a reduction of particulates on the environment, it is important to get a grasp on the impact of Addressograph-Multigraph's emissions on the air quality in the surrounding area. Needless to say, any level of detail in this type of analysis could be undertaken. It is thus necessary to arrive at a

"feel" for how significant the effect of the effluent would be and tailor the analysis accordingly. In the present case, the effects are expected to be very small, and verification will be conducted at preset meteorological conditions.

A) Short Term Effect (Less than 10 Minutes)

This effect can be found by applying the equations found in Turner's "Workbook on Atmospheric Dispersion" and Briggs' plume rise equation. [17]* Appendix C details the calculations run to arrive at the short-term estimates. Overall results are shown in Table 4.1 and Figure 4.1. Calculations were run at Class A and Class D stability under a constant wind speed of 10 mph ($4.47^{m/sec}$). All incinerator data was obtained from Addressograph-Multigraph's permit application file at the Illinois Environmental Protection Agency.

Results show a maximum Class A reading of 1.9 ug/m^3 at 0.25 km from the stack. The maximum readings shown here are the result of a separate graphical interpolation, and are thus above the reading expected from a direct graphical presentation of the calculated data (e.g., Class A, max. = 1.9 calc. vs 1.2 ug/m^3 via graph).

These short term readings should not be compared to any recognized standards in that they are of very short duration and are meant to show maximum possible peaks (i.e., less than 10 minutes).

*Briggs' equation is more appropriate for small stacks and is now being almost universally applied by the Illinois Environmental Protection Agency.

B) 24-Hour Effect

The 24-hour effect is somewhat more useful in that it can be compared against an existing national standard:

	24 hr. Standard	Annual Standard
Primary Standard	260 $\mu g/m^3$	75 $\mu g/m^3$
Secondary Standard	150 $\mu g/m^3$	60 $\mu g/m^3$

In order to get a rough approximation of the 24-hr. concentration which would result from Addressograph-Multigraph's emissions, the equation

$$Xs = Xk\left(\frac{Tk^p}{Ts}\right)$$ in which

Xs = Desired Concen., $\mu g/m^3$
Xk = Known Concen., $\mu g/m^3$
Tk = Original Time, min.
Ts = New Time, min.
p = Barometric Pressure, μ bar

will be used.[16] Although this equation is more accurate at times less than 24 hours, it will yield a more conservative (higher) value than would actually occur when applied at 24 hours.[18] Utilizing this formula at Class A and D yields the results seen in Table 4.2 and Figure 4.2. The maximum concentration is predicted at 0.51 $\mu g/m^3$ for Class A stability and 0.38 $\mu g/m^3$ for Class D stability. Both of these values are

significantly below the standards, and could not be expected to affect the attainment of the primary or secondary 24-hr. air quality standard.

C) Annual Effect

A much more sophisticated methodology is required to assess the annual contribution of an emission to air quality. In essence, a summation of the contributions of particulates at a given point in space must be found. This summation is dependent upon (assuming a constant discharge) wind speed, wind direction, stability class, and other meteorological conditions.

Simply put, the short-term analysis assumes that meteorological conditions remain constant during the time of analysis. Concentration is thus a function of dispersion within a thin band. As meteorological conditions vary, particulate concentration at the point to be measured can change dramatically. Therefore, each of an infinite number of points in space will have a different maximum yearly concentration, due to fluctuations in meteorological conditions. In actuality a workable number of points in space and meteorological conditions are fed into a computer and concentrations are calculated. In the case of Addressograph-Multigraph's facility, the closest region for which good meteorological data exists is Springfield, Illinois.[19] Those data suggest that the most common stability class is D (Neutral Day), which occurs about

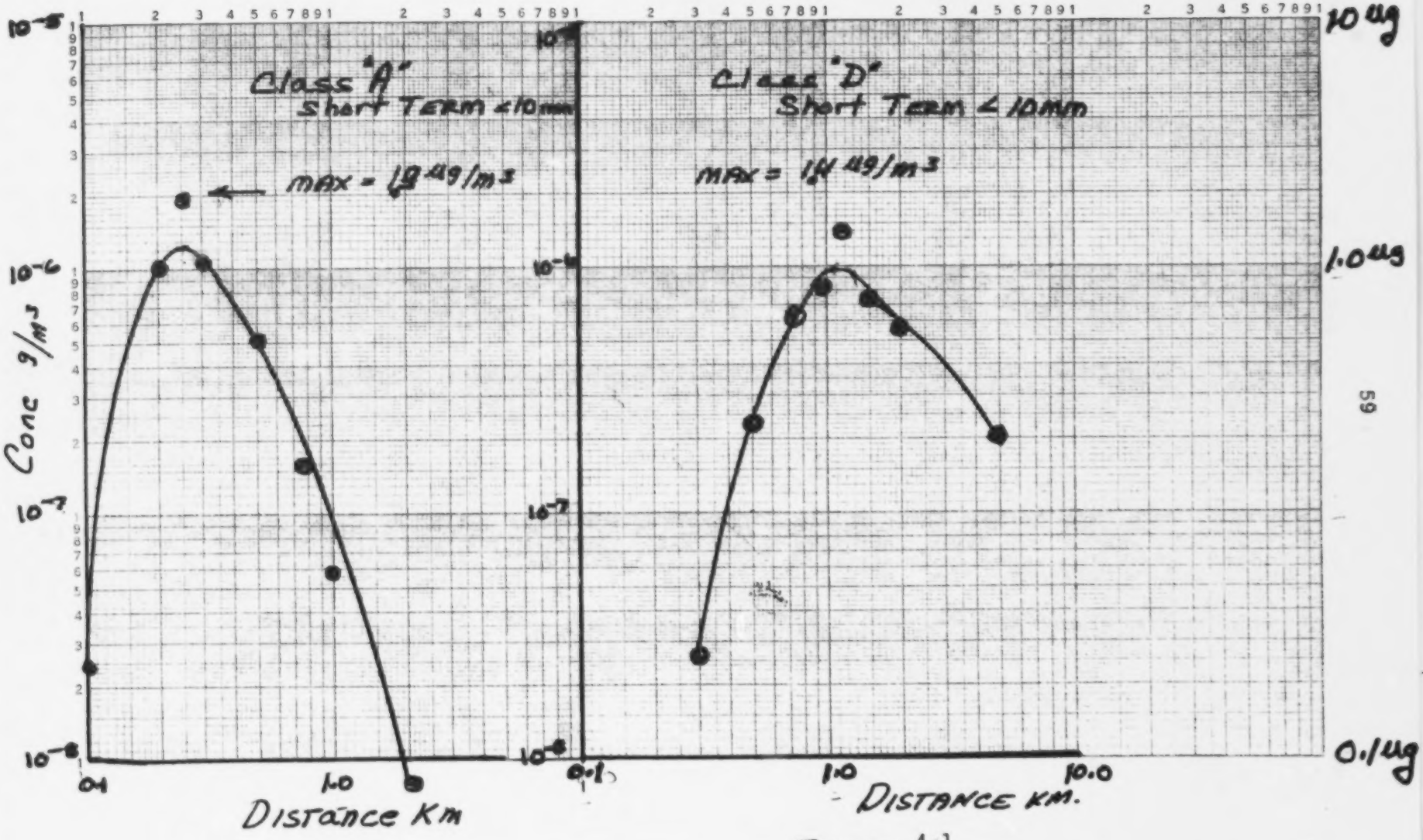
Class "A"
Short Term < 10mm
MAX = 19 µg/m³
Class "D"
Short Term < 10mm
MAX = 14 µg/m³
Conc g/m³
10 µg
1.0 µg
0.1 µg
Distance Km
Distance Km.

Figure 4.1

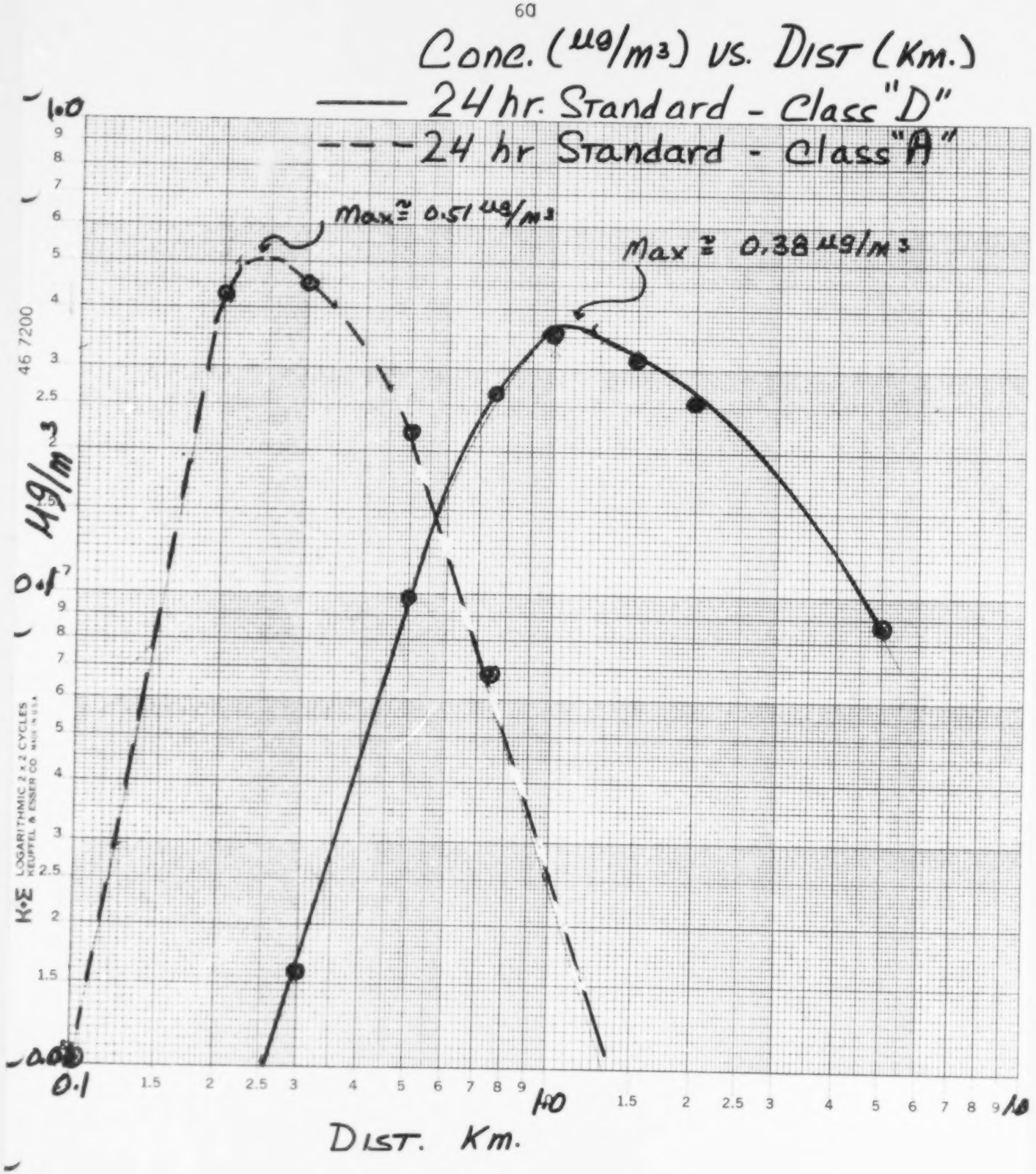
Conc. (μg/m³) vs. Dist (Km.)
—— 24 hr. Standard - Class "D"
- - - 24 hr Standard - Class "A"
Max ≅ 0.51 μg/m³
Max ≅ 0.38 μg/m³
μg/m³
Dist. Km.
K+E LOGARITHMIC 2 x 2 CYCLES
KEUFFEL & ESSER CO
46 7200

Figure 4.2

TABLE 4.1

Short Term (10 Min.) Air Quality Effects*

Distance Km	D - Stability ug/m^3 Concentration	A - Stability ug/m^3 Concentration
0.1	-	2.4×10^{-2}
0.2	5.3×10^{-7}	1.00
0.3	2.5×10^{-2}	1.10
0.5	0.23	0.51
0.75	0.61	0.16
1.0	0.81	5.9×10^{-2}
1.5	0.74	1.9×10^{-2}
2.0	0.58	8.0×10^{-3}
5.0	0.20	-

*At wind speed of 10 mph. Concentration at center line of plume.

TABLE 4.2

24-Hour Air Quality Effects*

Distance Km	D - Stability ug/m^3 Concentration	A - Stability ug/m^3 Concentration
0.1	-	0.01
0.2	2.3×10^{-7}	0.43
0.3	1.1×10^{-2}	0.45
0.5	9.7×10^{-2}	0.22
0.75	0.27	0.07
1.0	0.35	2.5×10^{-2}
1.5	0.32	-
2.0	0.25	3.4×10^{-3}
5.0	0.08	-

*At wind speed of 10 mph. Concentration at center line of plume.

32% of the time. At times of Class D stability the most prevalent wind speed and direction are about 10 mph from the south, occurring about 2.5% of the time. These data lead to the assumption that the short-term concentrations such as calculated above will be found downwind of a southerly wind. The criteria which lead to this short-term peak exist only 2.5% of the time. During the other 97.5% of the time the specific point in space is being influenced by other wind speed and directions, and a smaller "contributed" concentration will be found at that point. The annual concentration at any point is the sum of the weighted contributions at all points in space.

Needless to say, the maximum annual concentration at any given point will be significantly lower than the twenty-four hour concentration at a given point. To arrive at an accurate projection a detailed computer analysis would be required. Such a detailed analysis was considered unnecessary for this case because of the relatively small (0.38 $\mu g/m^3$) short-term concentration. A very rough (and very conservative) estimate of the annual projection can be found by employing the same equation utilized in going from the 10-minute peak to the 24-hr. peak. Utilizing the equation from 10 minutes to one year, an incremental concentration of 0.128 $\mu g/m^3$ is predicted; when going from 24 hours to one year a projection of 0.139 $\mu g/m^3$ is predicted.

The very low predicted "annual incremental additions" to

the air quality as a result of Addressograph-Multigraph's emissions verify that a full-blown computer analysis would be unnecessary for this study. In calculating projected benefit (Section 4.2, Table 4.7) the 0.128 $\mu g/m^3$ projection will be used. The reader is once again reminded that this figure is extremely conservative and will thus yield benefits on the high side.

D) Present Air Quality in Charleston Area

Unfortunately there are no monitoring stations in Charleston, Illinois, and thus a direct readout of the air quality is unavailable. The author could only infer the quality at Charleston from surrounding area monitors. In that Environmental Protection Agency monitoring sites are usually selected because of relatively higher emissions in the area, it is logical to assume that the Charleston area will be somewhat below that of the surrounding, directly monitored cities.

The Addressograph-Multigraph facility is located in the Illinois Environmental Protection Agency Air Quality Control Region 66, relatively close to Air Quality Control Region 74. The two closest particulate monitoring stations are located at Champaign to the north and Effingham to the south. Table 4.3, extracted from 1976 Illinois Environmental Protection Agency records, displays the air quality in the Champaign and Effingham areas.

TABLE 4.3

Air Quality in Champaign and Effingham

Station	Address	Number of Samples			Highest Samples				Annual Statistic	
		Total	>150 $\mu g/m^3$	>260 $\mu g/m^3$	1st	2nd	3rd	4th	Geometric Mean	Std. Geo. Deviation
Champaign County										
Champaign	2125 South First	53	1	1	272	132	122	112	56	1.66
Effingham County										
Effingham	1015 South Willow	40	1	0	154	118	105	82	59	1.45

It should be noted that one sample exceeding the standard does not constitute a violation. This is because the standard is written to allow no more than one reading per year above the prescribed level.

As can be seen from this data, both sites show particulate levels below the annual secondary standard of 60 $\mu g/m^3$, and well below the primary of 75 $\mu g/m^3$. It should also be noted that while Champaign recorded one sample over the 24-hr. primary standard, Effingham (by far the closer station) had as its highest reading a value of 154 $\mu g/m^3$ which is only slightly above the secondary standard (150 $\mu g/m^3$).

Given the above information, it is reasonable to assume that the air quality within the Charleston area is safely within the applicable air quality standards. Moreover, complete elimination of emissions from the Addressograph-Multigraph facility should not change the surrounding air quality to any significant degree; at most, plant closing might lower the 24-hr. air quality level by about 0.5 $\mu g/m^3$, and the annual level by a maximum of 0.14 $\mu g/m^3$.

4.2 Benefits Resulting from Emission Reductions

Having estimated the effects of Addressograph-Multigraph's total emissions on the environment, the analyst can begin to study the economic benefits which would accrue should such emissions no longer exist, or exist in lesser quantities. Unfortunately, it is extremely difficult to perform such an analysis. Data in previous studies either relate to large volumes of particulate emissions, or to the effects of pollution reduction in areas with high pollution levels. Neither condition holds true in the present case. Rather, the Addresso-

graph-Multigraph situation concerns relatively minor reductions in air pollution in a relatively clean environment.

Notwithstanding the above, an estimate of the benefits can be made. While these estimates must by necessity rely on national figures, the overall results can be applied to the Charleston area.

Barrett and Wadell[20] undertook a comprehensive review of research to date involving monetization of pollution effects. Effects in four areas (residential property, materials, health, and vegetation) were analyzed. Emissions were broken down by type of pollutant as well as emission source category. For each effect, estimates of the relative impact of each pollutant were made.

The impact of incinerator emissions can be related to total emissions first on a national level. Having made this comparison, costs can be further scaled down to estimate the effects of operating the Addressograph-Multigraph incinerator. Barrett includes incinerators in the solid waste category with other types of emission sources. A mix of emissions therefore exists which is not similar to the 100% particulate emissions with which this report is concerned. Thus when cost estimates are extrapolated from national figures, they must be adjusted to reflect the impact of particulates only. Table 4.4 shows so-called external costs on a national basis for all pollution sources, and specifically for solid waste sources. Column 1 defines the impact categories. Columns 2

and 3 list the costs by category due to all pollution sources. Column 2 relates the cost for all pollutants while Column 3 relates that fraction of the costs attributable to particulates alone. Columns 4 and 5 are similar to 2 and 3, but refer to solid waste sources only. Note again that incinerators fall in the solid waste category. The percentage of costs attributable to particulates for the "total source" category differs significantly from that for solid waste (e.g., 46% total source vs. 92% as regards the health effects). This discrepancy stems from the difference in the types of pollutants emitted in each category.

In 1968, total particulate emissions in the United States were 28.3 million tons, and of that total 1.1 million tons are attributable to solid waste sources.[20] These figures can be used to generate a rough cost/ton for particulate emissions. These costs are shown in Table 4.5.

The figures in Table 4.5 are based on the portion of a pollutant's effect on a specific category, as well as on the ratio of that pollutant to total discharge. For example, effects on health are considered to be in direct proportion to the amounts of sulphur dioxide and particulates present In the case of solid wastes we have the following data:

Tons sulphur dioxide emitted	= 0.1 million tons
Tons particulates emitted	= 1.1 million tons
Total health effects of solid waste category	= 0.119 billion dollars

Health costs attributable to particulates from solid waste sources = $0.119 \times 1.1 \div 1.2 = 0.109$ billion dollars, or

$$\frac{0.109 \times 10^9}{1.1 \times 10^6} = \$99.16/\text{ton}.$$

TABLE 4.4

Nationwide Costs for Pollution Damage
By Pollutants/Particulates/Solid Waste

(Billions of Dollars)

Benefit (Category)	Costs from All Pollutants	Costs from Particulates	Solid Waste	
			All Pollutants	Partic.
Residential Property	5.20	2.40	0.104	0.095
Materials	4.75	0.69	0.143	0.046
Health	6.06	2.79	0.119	0.109
Vegetation	0.12	0.007	0.004	.0002
Total	16.13	5.887	0.370	0.250

Source: Reference 20

TABLE 4.5

Cost/Ton of Particulate Emissions

Benefit (Category)	Total National Particulate $/Ton	Total National Solid Waste Particulate $/Ton
Residential Property	$84.50	$86.66
Materials	24.44	42.05
Health	98.51	99.16
Vegetation	0.25	0.21
Total	$207.70	$228.08

In order to utilize these figures for the Addressograph-Multigraph facility, two assumptions are made. First, it is assumed that the costs/ton are equal for all sources, regardless of the location or degree of pollution of the surrounding area. This assumption should overestimate the costs attributable to Addressograph-Multigraph's facility, in that it is generally accepted that costs associated with pollution are greater in more polluted areas. Second, it is assumed that the costs/ton due to Addressograph-Multigraph's incinerator are similar to the broad classification of solid waste.

On the basis of 3.63 tons of particulates per year, costs attributable to Addressograph-Multigraph's incinerator are as shown in Table 4.6.

TABLE 4.6

Costs Attributable to Emissions from Addressograph-Multigraph's Incinerator (Particulate Fallout Method)

Benefit Category	1968 - $	1977 - $
Residential Property	$314.58	$543.42
Materials	152.64	263.68
Health	359.95	621.79
Vegetation	0.76	1.31
Total	$827.93	$1430.20

The 1977 figure is a reflection of the cost of living index escalator between the 1968 data presented in Ref. 20 and 1977.*

Another method for assessing the benefits derived from a specific reduction in air pollution was undertaken by Cohen et al.[21] The technique was to calculate the incremental value of given events as a function of a one microgram/meter cubed reduction in particulate loading. Events chosen were

*CPI, 1968 = 104.2, CPI mid-1977 = 180.

"Life expectancy," "Health care," "Material maintenance," and "Other uses." An attempt is made here to extrapolate the data derived by Cohen to the Charleston area. However, since Cohen's data are site-specific (to the Chicago area), two points should be kept in mind:

1. Chicago air quality is worse than that of Charleston. Therefore, a one $ug/_m{}^3$ reduction in Charleston may not have the same effect as a one $ug/_m{}^3$ reduction in Chicago. Although Cohen appears to assume that costs are independent of initial air quality, this was only assumed over the Chicago area range. In any event, it is logical to assume that, given the generally better air quality in Charleston, the figures generated for costs will be on the high side.
2. Much of the basic economic data in Ref. 21 is from the Chicago area. Thus this study makes the implicit assumption that Charleston residents pay approximately the same cost for services (such as health care) as do Chicagoans. Like # 1 above, this assumption should produce costs on the high side due to the higher cost of living in the Chicago area.

Cohen's data are tabulated in terms of dollars/household for two million Chicago area households. He uses a 10% soc-

ial discount rate and reports figures in terms of their present value. (The results in Table 4.7 adjust for the discount rate by using the implied one-tenth initial cost.)

TABLE 4.7

Benefits of a one $\mu g/m^3$ Reduction in Annual Particulate Air Quality Level

Benefit (Category)	$/Household		Total $ x 10^6	
	1972	1977	1972	1977
Life expectancy				
Extension of earnings	0.54	0.78	1.08	1.55
Deferred expense	0.031	0.04	0.06	0.09
Reduced health care	1.40	2.01	2.80	4.02
Material maintenance	4.50	6.46	9.00	12.93
Other uses	1.70	2.44	3.40	4.88
Total	8.17	11.73	16.34	23.47

To apply the costs in Table 4.7 to the Charleston area requires knowledge of the number of households and the expected annual reduction in particulate levels. As discussed above, a particulate level reduction of 0.128 $\mu g/m^3$ is expected. The standard household may be considered to consist of 3.2 persons. With 16,416 in Charleston, 5,130 households are postulated. Because of the volume of emissions under consideration, it is expected that no persons outside of the Charle-

ston area will be affected. From the information in Table 4.7 and the data given above, Table 4.8 is constructed, which predicts the costs attributable to emissions from the Addressograph-Multigraph incinerator.

TABLE 4.8

Costs Attributable to Emissions from Addressograph-Multigraph's Incinerator (Air Quality Method)

Benefit Category	$/Household/Yr	Total $/Yr
Life expectancy		
Extension of earnings	0.10	$512.18
Deferred expenses	0.005	26.27
Reduction of health care	0.26	1319.85
Materials maintenance	0.83	4241.89
Others	0.31	1602.20
Total	1.505	$7702.39

It is obvious that certain benefits may not be covered in either analysis. This is because the impact is negligible or data do not exist to accurately assess the impact.

The above two approaches yield savings from $1,430 to $7,702 per year, which range probably includes most of the benefits resulting from elimination of the emissions at the Addressograph-Multigraph incinerator. Although these two esti-

mates may seem to describe a rather wide range, there are good reasons for this polarity. First and foremost, extrapolation from such low level emissions magnifies any error. The analysis utilized to arrive at an expected reduction in air quality, by its nature, yields a high projection. Given uncertainties of this type, the estimates are reasonably close.

Chapter 5

Cost/Benefit Comparisons

Chapters 3 and 4 detail the costs and benefits associated with proposed Regulation R77-5. The purpose of this chapter is to present the results side by side so that an intelligent assessment of the results can be made.

In summary, costs to reduce emissions can arise in three ways: retrofitting the existing incinerator; utilizing an alternate technology; or shutting down operations. The costs associated with each of these options can be compared with the benefits derived by one of two methods. Another approach to the comparison of costs and benefits would calculate the tons of emissions and consequent loss of benefit necessary to justify projected costs. The results of these comparisons appear in Table 5.1.

Table 5.1 reveals that by each method of comparison the costs of control outweigh (economically) the benefits derived. A note of explanation regarding Table 5.1 is in order.

Costs shown in Table 5.1 (Column 1) are those incremental costs which occur as a result of new expenditures required of Addressograph-Multigraph in order to meet the existing regulation. Thus in the case of the retrofit options, costs reflect only the operations and capital recovery of a bag-house, electrostatic precipitator, or Venturi. It should be

remembered that these retrofit costs are above the cost of operating the incinerator (which is $109,200/yr.). This point is of critical importance when retrofit options are compared against the other options.

New technology options (i.e., reverse osmosis, contract disposal) are costed from the ground up. Therefore, they not only abate incremental pollution which would be the subject of concern in R77-5, but become the total pollution abatement system.

This report uses the approach that incremental costs must be tied to incremental benefits. While, in the author's opinion, this is a proper approach, it does tend to skew the cost/benefit analysis in the favor of retrofit. When considering overall actual costs, such may not be the case.

Columns 6 and 7 of Table 5.1 include an estimate of how much additional fallout (6) or what additional degree of air quality degradation would be necessary to reach an economic cost/benefit break even. For example, if 3.63 tons of particulates are removed by the expenditure of $14,419 (bag-house retrofit), this would result in a benefit of $1430. Then $14,419 ÷1430 x 3.63 tons would equal 36.6 tons of material. This is the tonnage (36.6) which would theoretically have to be reduced at break even. Likewise for the air quality analysis: 14,419 ÷7702 x 0.128 = 0.240 $\mu g/m^3$.

TABLE 5.1

Cost/Benefit Analysis

Method of Cost	Calculated Cost	Benefit via Tons Emitted	Cost/Benefits	Benefits via Air Quality Red.	Cost/Benefit	Emissions to Reach Break Even	Air Quality Degradation to Reach Break Even
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$	$	$(1-2)	$	$(1-4)	Tons/Yr.	$\mu g/m^3$
Baghouse Retrofit	14,419	1430	12,989	7702	6,717	36.6	0.240
ESP - Retrofit	17,960	1430	16,530	7702	10,258	45.6	0.298
Venturi - Retrofit	30,172	1430	28,742	7702	22,470	76.6	0.501
Reverse Osmosis	23,760	1430	22,330	7702	16,058	60.3	0.395
Contract Disposal - High	137,280	1430	135,850	7702	129,578	348.5	2.28
Contract Disposal - Low	72,800	1430	71,370	7702	65,098	184.8	1.21
Cessation of Operations*	4,083,526	-	-	-	-	-	-

*This option is calculated as the total of lost wages, lost revenue, and lost taxes. It thus is unrealistically high and presented only for the sake of completeness.

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* Numbers in parentheses refer to citations of references in text.

Appendix A

Mathematics of 12% Conversion Factor

The subject rule 203(e) requires that incinerator particulate emission concentrations, as measured, be corrected to a volume concentration corresponding to 12% carbon dioxide. In order to utilize this correction, the carbon dioxide contribution from the waste to be incinerated is used.

For incinerators allowable particulate emission rates are quoted on a mass/volume basis. Typical units are grains/standard cubic foot of gas. As applied in this case, the limitation is 0.1 $^{gr}/_{ft^3}$.

In the case of incinerators it is necessary to specify one other parameter before the above quoted code levels can be meaningful. One can see that if particulate emissions are quoted on a mass/time basis there is little ambiguity about this. However, if emissions are quoted on a mass/volume basis, then with a combustion operation, such as incinerator, comparison of measured emissions with prevailing cases can be problematical due to different combustion operations requiring different air volumes and effluent dilutions.

This situation is overcome in all incinerator effluent codes, where the codes are written in terms of a particulate effluent mass/volume concentration basis, by quoting the codes at a specific excess air ratio.

Consequently incinerator codes are frequently quoted as a

not to exceed figure in terms of "grains per standard cubic foot of dry gas corrected to 12% CO_2." (These units are abbreviated to grains/scf db at 12% CO_2.) In this way a definitive and meaningful code is written. Specification of a code level in terms of grains/scf db at 12% CO_2 is the most usual way. However, it is equally possible to either convert this figure to grains/scf db at a specified excess air ratio , or lbs/1000 lbs of exhaust gas as is or at a 12% CO_2 figure or corresponding excess air figure.

Due to the historical use of incinerators to burn garbage, and the fact that garbage is basically a carbonaceous material, the correction to 12% CO_2 is performed based upon the CO_2 contribution from the garbage being incinerated.

For example, a certain incinerator grain loading is measured at a certain CO_2 level. This can be corrected to 12% CO_2 (or indeed any other CO_2 level in the following way) to determine degree of compliance of the local air pollution codes:

$$C_{12\%\ CO_2} = C_M \times \frac{12}{V_{CO_2}} \qquad (1)$$

where

$C_{12\%\ CO_2}$ = particulate concentration in grains/scf db corrected to 12% CO_2

C_M = measured particulate concentration in grains/scf db

V_{CO_2} waste = measured CO_2 (as a %) resulting from the combustion of waste only

In the event the CO_2 is produced from other sources within the incinerator then appropriate allowance has to be made for this, viz:

$$V_{CO_2} \text{ waste} = \text{measured } CO_2 - \sum(\text{all other burner contributions of } CO_2) \quad (2)$$

Essentially this implies that the CO_2 contributions from all other incinerator burners which are used to promote efficient burning have to be deducted from the measured CO_2 value to arrive at the CO_2 contribution to the effluent gas total CO_2 contribution before the CO_2 contribution from the waste can be determined. Basically all such burners have to be considered including:

ignition burners
primary chamber auxiliary burners
after burners

In the event these burners cycle on-off or from high to medium to low fire, then an appropriate pro-rated allowance has to be made for these cycle times.

It is obvious all these adjustments have to be included since higher final effluent CO_2 figures can be obtained by use of one or more additional burners in an incinerator, and since the correction to 12% CO_2 is proportional to the reciprocal of the measured CO_2 level minus other CO_2 inputs, then an incorrect (and low) correction is made.

Finally it should be mentioned that in the event a scrubber is incorporated, an allowance has to be made for this since CO_2 will dissolve in the scrubber water and result in low observed CO_2 values:

$$V_{CO_2 \text{ waste}} = \text{Measured } CO_2 - \sum(\text{all other burner contributions of } CO_2) + (\text{correction factor for } CO_2 \text{ loss in scrubber}). \quad (3)$$

All of the above discussion concerns corrections of measured particulate emissions to a 12% CO_2 basis, based upon CO_2 contributions from the garbage. This methodology is most frequently used as already stated.

Other methods of data treatment are possible (as already indicated above) and indeed are used in certain instances.

Correction of emission data to a 12% CO_2 base is the most popular method: it, however, does have one major deficiency

in that it assumes the garbage is carbonaceous. In the event the "garbage" to be burnt is not a carbonaceous-based material, then this method is not really applicable since no CO_2 will result from burning of the waste, that is V_{CO_2} waste = 0, hence the correction detailed in Equation (1) causes $C_{12\%CO_2}$ to become infinite ($C_{12\%CO_2} \rightarrow \infty$).

Consequently utilization of $12\%CO_2$ as a correction basis or indeed any other CO_2 figure has a major deficiency. This deficiency occurs only in cases such as the one under consideration and does not destroy the validity of the 12% conversion factor as applied to the vast majority of incinerator applications.

Appendix B.1

State of Illinois Air Pollution Regulations

Rule 203(e)

(e) Particulate Emission Standards and Limitations for Incinerator

(1) No person shall cause or allow the emission of particulate matter into the atmosphere from any incinerator burning more than 60,000 pounds of refuse per hour to exceed 0.05 grains per standard cubic foot of effluent gases corrected to 12 per cent carbon dioxide.

(2) No person shall cause or allow the emission of particulate matter into the atmosphere from any incinerator burning more than 2000 pounds of refuse per hour to exceed 0.08 grain per standard cubic foot of effluent gases corrected to 12 per cent carbon dioxide.

(3) No person shall cause or allow the emission of particulate matter into the atmosphere from all other existing incinerators to exceed 0.2 grains per standard cubic foot of effluent gases corrected to 12 per cent carbon dioxide.

(4) No person shall cause or allow the emission of particulate matter into the atmosphere from all other new incinerators to exceed 0.1 grains per

standard cubic foot of effluent gases corrected to 12 per cent carbon dioxide.

(5) Exception: Subparagraphs (1), (2) and (4) of this Rule 203(e) shall not apply to incinerators which burn wood wastes exclusively, if all the following conditions are met:

(A) The emission of particulate matter from such incinerator does not exceed 0.2 grains per standard cubic foot of effluent gases corrected to 12 per cent carbon dioxide; and,

(B) The location of such incinerator is not in a restricted area, and is more than 1000 feet from residential or other populated areas; and,

(C) When it can be affirmatively demonstrated that no economically reasonable alternative method of disposal is available.

Appendix B.2

Proposed Amendment to Rule 203(e)

PETITION TO AMEND RULE 203(e) COMPUTATIONS FILED

The Addressograph-Multigraph Corporation has amended its Petition to Amend Rule 203(e) of the Board's Air Pollution Regulations. This amendment would provide for a 50% excess air correction instead of a 12% CO_2 correction for incinerators burning low carbon aqueous waste. The next hearing on this matter shall be held on October 18, 1977 in Room 503 of the Circle Center at the University of Illinois Chicago Circle Campus. The hearing shall start at 10:00 a.m. If you would like to give any testimony on this proposal, please contact Rich Christopher at the Board office in Chicago. A complete text of the proposed amendment follows:

"203(e)(4)(A). Rule 203(e)(4) shall not apply to aqueous waste incinerators which, when corrected to 50 per cent excess air for combined fuel and charge incineration, produce stack gas containing carbon dioxide dry-basis volume concentrations of less than 1.2 per cent from the charge alone; if all the following conditions are met:

(i) The emission of particulate matter into the atmosphere from any such new or existing incinerator does not exceed 0.1 grains per

standard cubic foot, dry basis, when corrected to 50 per cent excess air for combined fuel and charge incineration.

(ii) The waste charge to the incinerator does not exceed 2000 pounds per hour."

Appendix C

Short Term Air Quality Impact Methodology

Conditions of Addressograph-Multigraph facility:

Discharge = Q = 1.163#/hr $0.1467^{gm}/_{sec.}$

π = 3.14

Assumed Wind Speed = μ = 10 mph $4.47^{m}/_{sec.}$

Atmospheric Pressure = P = 970 μ bar.

Discharge Temp. = Ts = 2135°k

Ambient Temp. = Ta = 510°k

Diameter of Stack = D = 40.5" = 1.03M

Velocity of Discharge Gas = V = 24 $^{ft}/_{sec}$ = $7.32^{m}/_{sec.}$

Height of Stack = Ha = 33 $^{ft.}$ = 10.06^{m}

Briggs' Plume Rise Equation:

1. Calculate heat emission rate:

$$Qh = 67\ D^2\ V \left[\frac{T_s - 286}{T_s}\right]$$

$$Qh = 6.7(1.03)^2\ (7.32) \left[\frac{2135 - 286}{2135}\right]$$

$$Qh = 449.47\ \frac{kcal}{sec.}$$

2. Calculate Plume Rise (Δh)

$$\Delta h = \frac{0.54(Q_h)^{.75}}{(Ha)^{.11}}$$

$$\Delta h = \frac{0.54(449.47)^{.75}}{(10.06)^{.11}}$$

$$\Delta h = 40.89 \text{ m.}$$

3. Calculate effective height:

   He = Hat Δh

   He = 10.06 + 40.89

   He = 50.95 M.

Assume stability classes A and D:

1. Use Turner Handbook, pg. 8-9, to arrive at Gy and G2 at various distances.

	D Stability		A Stability	
Dist km	Gy m	G2 m	Gy m	G2 m
0.1	5.0	4.6	27	18
0.2	15.0	8.4	50	30
0.3	24	14	72	50
0.5	35	18.5	110	100
0.75	52	25	165	240
1.0	70	32	240	450
1.5	100	43	300	1100
2.0	130	50	400	2000
5.0	300	90	870	-

2. Calculate concentration along center line of plume at various distances, for both stabilities, at 10 mph wind speed.

$$Xx, o\ o, h = \frac{Q}{\pi G_x G_z M} \exp\left[-1/2\left(\frac{He}{G^2}\right)^2\right]$$

Example at Class D, 1.0 km.

$$X = \frac{0.1467}{(3.14)(70)(32)(7.32)} \exp\left[-1/2\left(\frac{50.95}{32}\right)2\right]$$

$$X = 8.06 \times 10^{-7}\ gm/_{m}^{3} = 0.806\ ug/_{m}^{3}$$

Table 4.1 and Figure 4.1 of Chapter 4 give overall results of such analysis.

3. Calculate maximum concentration points.

From plot of above information (Figure 4.1 and Figure 4.2) the distance to maximum concentration is:

Stability D = 1.08 km

Stability A = 0.25 km

Using pg. 16 of Turner (Fig. 3-5F) values for X/Q are found as:

Stability D = 0.45×10^{-4}

$$\text{Stability A} = 0.58 \times 10^{-4}$$

and maximum concentrations are:

$$D = 1.4 \times 10^{-6} = 1.4 \text{ ug}/\text{m}^3$$

$$A = 1.9 \times 10^{-6} = 1.9 \text{ ug}/\text{m}^3$$

Extrapolate short term results to 24-hr. results:

1. Utilize equation 5.12 from Turner.

$$Xs = Xk\left(\frac{Tk}{Ts}\right)^{p}$$

Xs = Desired concentration at sampling time

Xk = Concentration at shorter time

Tk = Shorter sample time (10 min.)

Ts = New sample time (24 hrs.)

p = between 0.17 and 0.2

2. Run calculations on all short-term results.
   Example: Class D, 1.0km, Xk = 8.06×10^{-7} gm/m^3

$$Xs = 8.06 \times 10^{-7}\left(\frac{10}{24(60)}\right)^{.17}$$

$$Xs = 3.46 \times 10^{-7} = 0.346 \text{ ug}/\text{m}^3.$$

APPENDIX D

ASSESSMENT WORKSHEET
CROSS-CHECKLIST FOR BENEFIT/RISK CONSIDERATION
economic impact study

Regulation No. R77-5 IIEQ Project No. 80.115 Title: An Economic Impact Study of Particulate Emission Standards for Combustion of Low Carbon Wastes

Prepared by Marder and Associates Date January, 1978

Pollutant Concentration Assessed Particulates

	LEVEL OF INFORMATION - IGNORANCE							
Benefit/Risk Categories	Descriptive Benefit/Risk Assessment	Reference	Amount of Risk	Units of Measure	Range of Risk Uncertainty	$ Value	Range of Uncertainty	Comments
Health Effects	Includes total of diseases such as respiratory ailments and cancers	20,21	Increases with age and nominal health of population		From 0 to 100% depending on part. fallout	622 - 1320	Diff. between two est.	Basic work from Lave & Seskin based on nat. $ scaled AS
Health Effects - Life Expectancy	Loss of earnings as a function of reduced life span	21	Varies as to race and age of population		Depends on air quality changes	512	-	Lave & Siskin data 1959-1961
Health Effects - Deferred Expenses	Deferring medical expenses for final illnesses and burial costs	21	Number of days costs deferred			26	-	Ave. cost of hospital stays & burial expenses

APPENDIX D (Cont.)

ASSESSMENT WORKSHEET (Cont.)

LEVEL OF INFORMATION - IGNORANCE

Benefit/Risk Categories	Descriptive Benefit/Risk Assessment	Reference	Amount of Risk	Units of Measure	Range of Risk Uncertainty ↓	$ Value	Range of Uncertainty	Comments
Materials Degradation	Corrosion of metals, concrete degradation, soiling of metals, textile soiling	20, 21	Depends on material, e.g., rust, repainting			264-4242	Diff. between two est.	Ref. 20, 21 based on extensive lit. review
Residential Property	Loss in property value as result of pollution	20	Depends on initial poll. level. Measures drop in mean property value		From 0-100%. Depends on part. fallout	544	Unknown	Based on 4 major studies
Vegetation	Loss in crop production and resultant loss to agriculture	20	Depends on crop level within sphere of influence		See preceding column	- 0 -	- 0 -	-
Other effects	Improved visibility, animal health, industrial equipment damage	21	Very variable depending on location		From 0-100%	1602	-	Compiled from many estmates